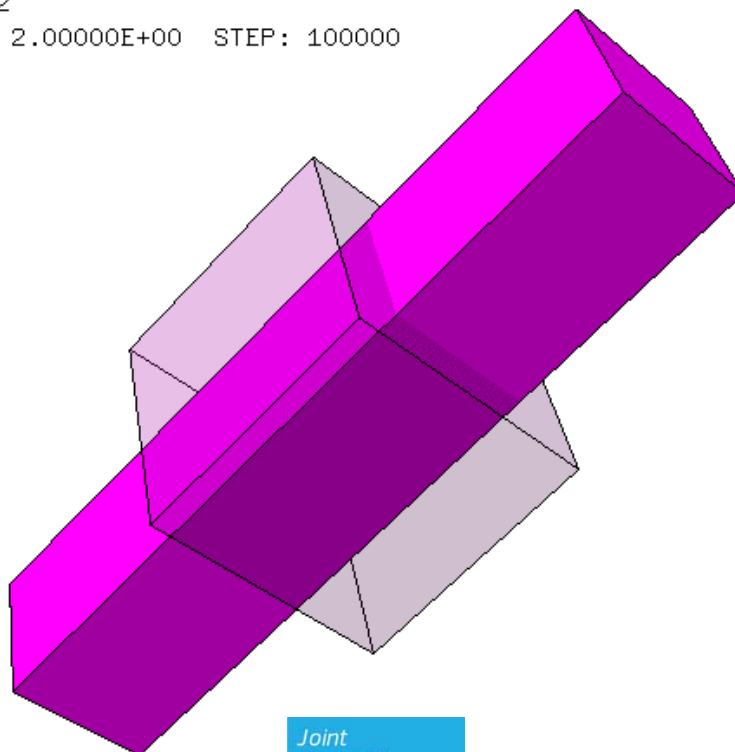


JRC TECHNICAL REPORTS

Testing of Johnson-Cook material model VPJC in EUROPLEXUS

Folco Casadei
Vegard Aune
Georgios Valsamos
Martin Larcher
2015

CUBE02
TIME: 2.00000E+00 STEP: 100000



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model VPJC in EUROPLEXUS

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1 Introduction

This document presents some numerical tests for the verification of the Johnson-Cook material model (VPJC) recently introduced in the EUROPLEXUS code (EPX).

EUROPLEXUS [1] is a computer code jointly developed by the French Commissariat à l’Energie Atomique (CEA DMT Saclay) and by EC-JRC. The code application domain is the numerical simulation of fast transient phenomena such as explosions, crashes and impacts in complex three-dimensional fluid-structure systems.

The Cast3m [2] software from CEA is used as a pre-processor to EPX when it is necessary to generate complex meshes.

2 The modified Johnson-Cook material model

We briefly recall the characteristics of the modified Johnson-Cook material model (VPJC material in EPX) adopted in the present report. This is a Von Mises elasto-thermo-viscoplastic material with non-linear isotropic hardening governed by a Voce saturation behaviour and a Cockcroft-Latham failure criterion, elastic predictor and return mapping algorithm. The material model was developed at NTNU (Trondheim, Norway), see [3].

The original Johnson-Cook model was first introduced in reference [4]. The so-called “modified” Johnson Cook material law, in which the strain-rate sensitivity term is adjusted so as to avoid non-physical softening, was introduced in reference [5] (see also [6]). The Voce saturation type of hardening was proposed in [7].

2.1 Constitutive law

The expression of the constitutive law is the following:

$$\sigma_Y = [A + Q_1 (1 - e^{-C_1 p}) + Q_2 (1 - e^{-C_2 p})] (1 + \dot{p}^*)^C (1 - T^{*m}) \quad (1)$$

and is the product of three factors (from left to right): a *strain hardening* term (in square brackets), a *strain-rate hardening* term and a *temperature softening* term. The symbols indicate the following:

- σ_Y is the current yield stress of the material.
- A is the initial yield stress of the material, sometimes also indicated as σ_0 .
- p is the equivalent (or cumulated) plastic strain, i.e. the energy-conjugated variable to the equivalent stress.
- \dot{p} is the equivalent plastic strain rate.

- \dot{p}^* is the dimensionless plastic strain rate $\dot{p}^* = \dot{p}/\dot{p}_0$, with \dot{p}_0 as the user-defined reference strain rate.
- T^* is the dimensionless temperature $T^* = (T - T_r) / (T_m - T_r)$, with T the absolute temperature, T_r the absolute room temperature and T_m the absolute melting temperature.
- Q_1 , C_1 , Q_2 and C_2 are material constants used in the first factor on the right-hand side of the material law (strain-hardening term).
- C is a material constant, the exponent appearing in the second factor, which represents the strain-rate hardening.
- m is a material constant, the exponent appearing in the third factor, which represents the temperature softening.

2.2 Temperature softening

The last term of the constitutive law (1) accounts for the thermal softening of the yield stress at elevated temperatures. However, the evolution of the temperature remains to be established. The heat transfer is modelled by assuming adiabatic conditions. This implies that there is no heat transfer into or out of the system (typically each individual element in the numerical model) during plastic straining.

The plastic energy dissipation D_p per unit volume in the form of heat (W/m³) is given by:

$$D_p = \chi \sigma_{eq} \dot{p} = \rho C_T \dot{T} \quad (2)$$

where:

- χ is the Taylor-Quinney coefficient, i.e. the fraction of plastic power that is converted to heat. The remaining fraction $(1 - \chi)$ is assumed to remain in the material due to structural rearrangements (i.e. elastic “fields” around dislocations). A value of 0.9 is commonly found in the literature for metals, however, a conservative choice would be 1.0 which implies maximum thermal softening. In reality the χ -value will not be constant, however, advanced experimental techniques are necessary to determine the evolution of this parameter. Moreover, one should always keep in mind that, while strain hardening (i.e. work hardening due to creation of dislocations) implies an increase of strength locally in the material and distributes the plasticity, softening results in localization of plasticity.
- σ_{eq} is the equivalent stress.
- \dot{p} is the equivalent plastic strain rate.
- ρ is the material density.
- C_T is the material heat capacity.
- \dot{T} is the temperature rate due to adiabatic heating.

From the above expression, the temperature rate \dot{T} is obtained:

$$\dot{T} = \frac{D_p}{\rho C_T} = \frac{\chi \sigma_{eq} \dot{p}}{\rho C_T} \quad (3)$$

and then this value is integrated in time at each Gauss point to obtain the current temperature at the point. The initial temperature is set to the room temperature T_r at each Gauss point. If during the calculation the temperature at a Gauss point reaches the melting temperature T_m , the Gauss point is assumed to fail.

2.3 Gauss point failure and element erosion

The Cockcroft-Latham fracture criterion based on plastic work per unit volume is assumed, see [8]. Material failure takes place at a Gauss point when a damage parameter D reaches the (user-defined) damage threshold D_C (with $0 < D_c \leq 1$). The value of D_c should be set to 1 when not considering damage softening. The damage is computed according to the following expression:

$$D = \frac{W}{W_c} = \frac{1}{W_c} \int_0^p \langle \sigma_1 \rangle dp \quad (4)$$

where:

- σ_1 is the maximum principal stress at the Gauss point.
- The expression $\langle \sigma_1 \rangle$ is equivalent to the function $\max(0, \sigma_1)$, which implies that only positive values of the maximum principal stress σ_1 (i.e. tensile stress) contribute to the damage evolution.
- W_c is the failure material parameter, which can be found by integrating the major principal stress in a uniaxial tension test during the entire equivalent plastic strain path until the plastic strain at failure p_f . In this case (uniaxial traction) the major principal stress is just the (longitudinal) stress.

An element's Gauss point is considered as *failed* if $D \geq D_c$, i.e. if the damage reaches the chosen threshold. If the “erosion” algorithm is activated (see [1], page A.30, Section 5.4, keyword **EROS**), then an element is *eroded* as soon as a chosen fraction (see **ldam** parameter of the **EROS** keyword) of its Gauss points reach failure.

3 Numerical tests

3.1 Uniaxial tests at constant velocity

The simplest possible test is a uniaxial test for a single element. A unit cube centered in the origin and aligned with the global axes is subjected to an imposed displacement (linear in time) of the faces normal to the z -axis (blue axis in Figure 1 (a)). The degrees of freedom along the other axes are left free. The “lower” face of the element (of nodes 1, 2, 3 and 4) is displaced along the negative z -axis while the “upper” face (of nodes 5, 6, 7 and 8) is displaced along the positive z -axis. The initial and final shape of the cube are shown in Figure 1 (a) and (b), respectively.

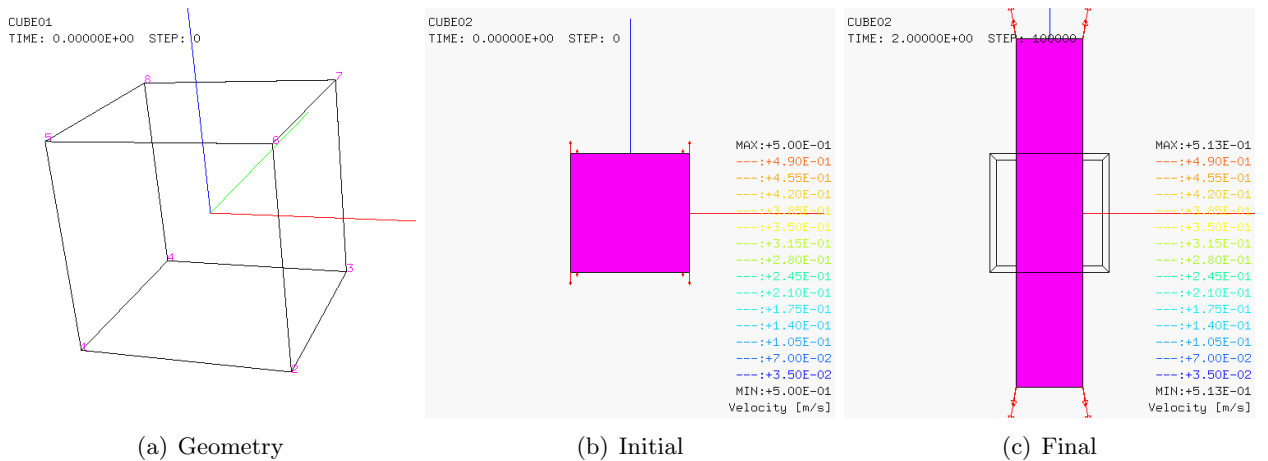


Figure 1: Uniaxial stress problem.

A first series of tests is done at constant velocity. The imposed (relative) velocity is 1 m/s (i.e. -0.5 m/s on the lower face and $+0.5$ m/s on the upper face). The final time of the calculation is 2 s, when the cube reaches a length of 3 m along the z -axis. This corresponds to an engineering strain of 200 % ($\epsilon = 2.000$) and to a natural strain of 109.9 % ($e = 1.099$).

This test is similar to the one proposed in reference [9] where, however, the elongation occurs along the x -axis instead of the z -axis, the calculation is stopped after an elongation of 1 m instead of 2 m, and the material is von Mises rate-independent elasto-plastic with isotropic hardening (VM23) instead of VPJC.

Although the imposed velocity is constant in this test, the strain rate is not constant due to the non-linear nature of large deformations. In order to simplify the test and to obtain an approximated analytical solution to be used as a reference, we assume a VPJC material insensitive to strain rate by setting $C = 0$. Also the temperature softening is neglected ($m = 0$).

3.1.1 Analytical static solution

Under these assumptions, the analytical solution of the equivalent static problem (i.e., by neglecting any dynamic or inertia effects, which is plausible since the imposed velocity is rather low) is obtained as follows. The longitudinal (natural) strain at the final elongation is:

$$e_z = \ln \left(\frac{L}{L_0} \right) = \ln \frac{3}{1} = 1.0986 \quad (5)$$

At such large strains the elastic deformations can be neglected compared with plastic deformations (which occur at constant volume), so that the volume remains approximately constant. Therefore, the lateral strains are:

$$e_x = e_y \approx -0.5e_z = -0.5 \times 1.0986 = -0.54931 \quad (6)$$

In a uniaxial stress case the equivalent plastic strain p is simply equal to the longitudinal plastic strain:

$$p = e_z^{\text{pl}} \quad (7)$$

If we again neglect the elastic part of the deformation, we have:

$$p = e_z^{\text{pl}} \approx e_z = 1.0986 \quad (8)$$

Since the stress is uniaxial and monotonically increasing in this test, the longitudinal stress σ_z coincides with the (current) yield stress σ_Y given by the constitutive law (1) which in this case ($C = 0$, $m = 0$) reduces to:

$$\sigma_z = \sigma_Y = A + Q_1 (1 - e^{-C_1 p}) + Q_2 (1 - e^{-C_2 p}) \quad (9)$$

With the assumed material parameters:

$$\begin{aligned} A &= 3.7 \times 10^8 \\ Q_1 &= 2.364 \times 10^8 \\ C_1 &= 39.3 \\ Q_2 &= 4.081 \times 10^8 \\ C_2 &= 4.5 \end{aligned} \quad (10)$$

and with the value of p given by (8), we obtain from (9):

$$\sigma_z \approx 10.116 \times 10^8 \quad (11)$$

and all other stress components are zero.

The longitudinal force at the final elongation is:

$$F_z = \sigma_z A_z \quad (12)$$

where A_z is the cross-section of the deformed specimen. Since the volume has been assumed to be approximately constant, and the final length is three times the initial one, the final cross-section must be:

$$A_z \approx \frac{1}{3} A_{z0} = 0.3333 \quad (13)$$

so that from (12):

$$F_z \approx 10.116 \times 10^8 \cdot 0.3333 = 3.3720 \times 10^8 \quad (14)$$

3.1.2 Calculations with continuum elements in 3D

The uniaxial calculations performed by EPX with constant velocity and no material sensitivity to strain rate and temperature are summarized in Table 1, for 3D continuum cases.

Case	Mesh	ϵ_x	ϵ_y	ϵ_z	σ_z	F_z
Analytical	—	-0.54931	-0.54931	1.0986	10.116×10^8	3.3720×10^8
CUBE02	CUBE	-0.54849	-0.54849	1.0986	10.081×10^8	3.3658×10^8
CUB802	CUB8	-0.54849	-0.54849	1.0986	10.081×10^8	3.3658×10^8
C81L02	C81L	-0.54850	-0.54850	1.0986	10.065×10^8	3.3606×10^8
C82L02	C82L	-0.54850	-0.54850	1.0986	10.065×10^8	3.3606×10^8
C272G2	C272	-0.54848	-0.54848	1.0986	10.150×10^8	3.3891×10^8
C273G2	C273	-0.54848	-0.54848	1.0986	10.150×10^8	3.3891×10^8
PRIS02	PRIS	-0.54848	-0.54848	1.0986	10.116×10^8	3.3777×10^8
PR6002	PR6	-0.54848	-0.54848	1.0986	10.116×10^8	3.3777×10^8
TETR02	TETR	-0.54848	-0.54848	1.0986	10.117×10^8	3.3778×10^8

Table 1: Calculations with 3D continuum elements.

CUBE02

The first case is CUBE02, which uses just one CUBE element. The input is:

cube02.epx

```

CUBE02
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 8 CUBE 1 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 -0.5 0.5 0.5
1 2 3 4 5 6 7 8
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
JAUM

```

```

CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dx_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 13 AXES 1.0 'STRESS [PA]' XAXE 23 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
FIN

```

Note that the JAUM option is activated. This is used in CEA continuum elements to treat large strains.

Some results are shown in Figure 2: the total strains, the stresses, the nodal forces and the stress *vs.* strain curve. The agreement with the analytical solution at the final time is very good, as shown

also in Table 1. Some small oscillations in the numerical solution are due to dynamic effects in the lateral directions, which are left free.

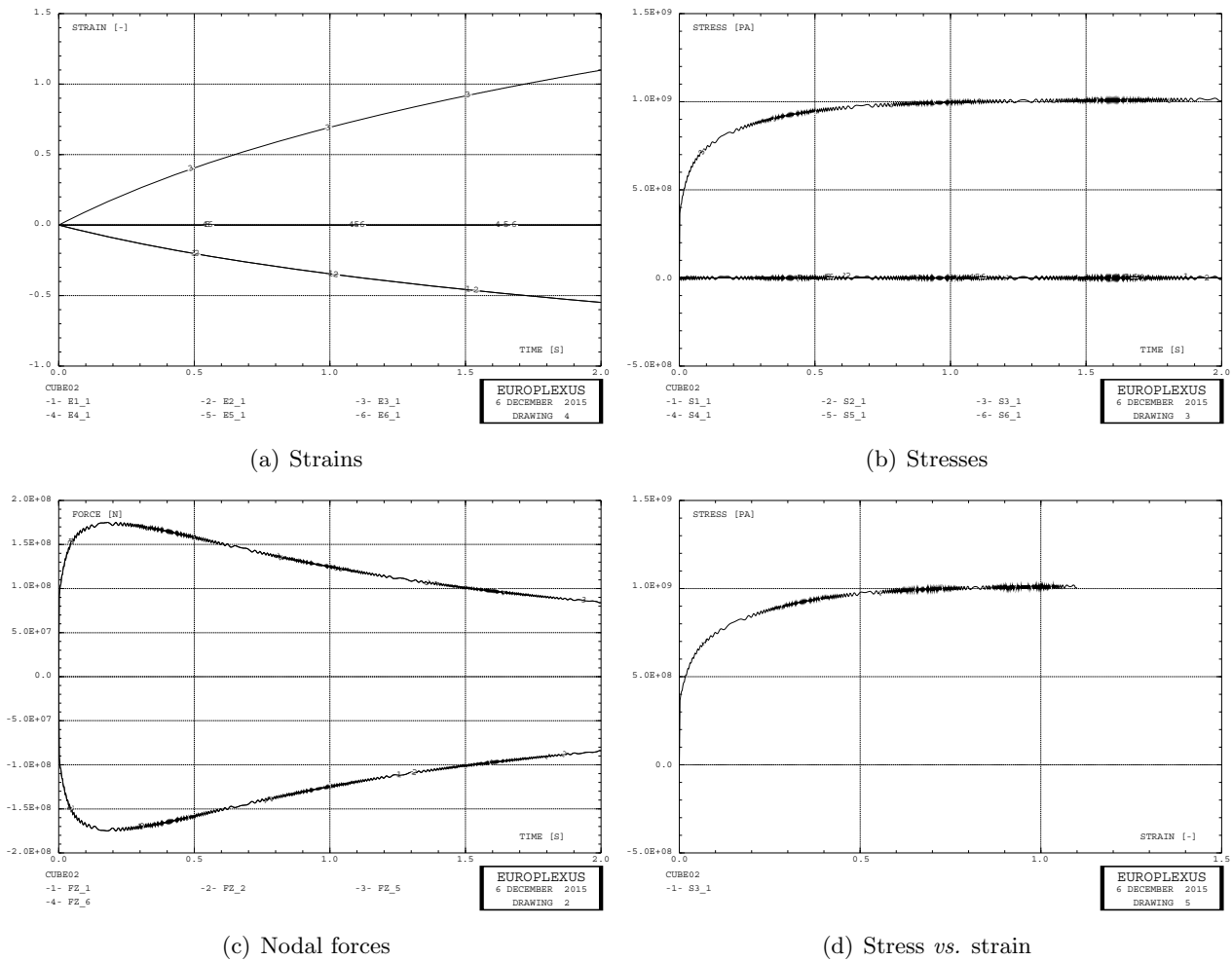


Figure 2: Some results of test case CUBE02.

CUB802

This test is similar to CUBE02, but uses the fully-integrated CUB8 element. Results are similar to those for the underintegrated CUBE element and in very good agreement with the reference.

C81L02

This test is similar to CUBE02, but uses JRC's underintegrated hexahedron element C81L. Results are similar to those for the underintegrated CUBE element and in very good agreement with the reference.

C82L02

This test is similar to CUBE02, but uses JRC's fully integrated hexahedron element C82L. Results are similar to those for the CUBE element and in very good agreement with the reference.

C272G2

This test is similar to CUBE02, but uses JRC's 27-node under-integrated parabolic hexahedron element C272. Like for the parabolic 2D continuum elements Q92 and Q93 mentioned below (see tests Q92G01 and Q93G01 in the next Section), this calculation suffers from mechanism-like motions which, however, can be suppressed by suitable RELA EGAL additional constraints, so as to achieve the correct results. The LINK directive for this test case is:

```
LINK COUP
```

```

VITE 3 -0.5 FONC 1 LECT 1 2 3 4 9 15 16 17 18 TERM ! Relative velocity
VITE 3 0.5 FONC 1 LECT 5 6 7 8 14 23 24 25 26 TERM ! 1 m/s
RELA 4 EGAL 1 LECT 1 4 5 8 13 18 19 22 26 TERM
      EGAL 1 LECT 2 3 6 7 11 16 20 21 24 TERM
      EGAL 2 LECT 1 2 5 6 10 15 19 20 23 TERM
      EGAL 2 LECT 3 4 7 8 12 17 21 22 25 TERM

```

C273G2

This test is similar to CUBE02, but uses JRC's 27-node fully-integrated parabolic hexahedron element C273. Like for the parabolic 2D continuum elements Q92 and Q93 mentioned below (see tests Q92G01 and Q93G01 in the next Section), this calculation suffers from mechanism-like motions which, however, can be suppressed by suitable RELA EGAL additional constraints, so as to achieve the correct results.

PRIS02

This test is similar to CUBE02, but uses two 6-node PRIS elements obtained by cutting the cube by a vertical diagonal plane. Results are similar to those for the CUBE element and in very good agreement with the reference.

PR6002

This test is similar to PRIS02, but uses two 6-node PR6 elements, the fully integrated version of the prism element. Results are similar to those for the CUBE element

TETR02

This test is similar to PRIS02, but uses twelve 4-node TETR elements, obtained by splitting the cube into 6 pyramids (one for each face of the cube) by adding a central node, and then by splitting each pyramid into two tetrahedra. Results are similar to those for the CUBE element and in very good agreement with the reference.

3.1.3 Calculations with continuum elements in 2D

Similar calculations are performed also in 2D continuum, plane stress conditions. In that case, traction is exerted along the y direction instead of the z direction. Results are summarized in Table 2. Recall that for continuum elements in EPX all quantities (both elemental ones like stresses and nodal ones like forces) are expressed along the global axes.

Case	Mesh	ϵ_x	ϵ_y	ϵ_z	σ_y	F_y
Analytical	—	-0.54931	1.0986	-0.54931	10.116×10^8	3.3720×10^8
CAR101	CAR1	-0.54894	1.0986	-0.54803	10.116×10^8	3.3777×10^8
CAR401	CAR4	-0.54894	1.0986	-0.54803	10.116×10^8	3.3777×10^8
Q41L01	Q41L	-0.54894	1.0986	-0.54803	10.116×10^8	3.3776×10^8
Q42L01	Q42L	-0.54894	1.0986	-0.54803	10.116×10^8	3.3776×10^8
TRIA01	TRIA	-0.54893	1.0986	-0.54802	10.116×10^8	3.3777×10^8
Q92G01	Q92	-0.54894	1.0986	-0.54803	10.116×10^8	3.3776×10^8
Q93G01	Q93	-0.54894	1.0986	-0.54803	10.116×10^8	3.3776×10^8

Table 2: Calculations with 2D continuum elements.

CAR101

This test is the 2D plane stress equivalent of CUBE02, and used CEA's underintegrated quadrilateral element CAR1. Results are similar to those for the CUBE element and in very good agreement with the reference.

CAR401

This test is similar to CAR101, but uses the fully integrated quadrilateral element CAR4. Results are similar to those for the CAR1 element and in very good agreement with the reference.

Q41L01

This test is similar to CAR101, but uses JRC’s underintegrated quadrilateral element Q41L. Results are similar to those for the CAR1 element and in very good agreement with the reference.

Q42L01

This test is similar to Q41L01, but uses the fully integrated quadrilateral element Q42L. Results are similar to those for the CAR1 element and in very good agreement with the reference.

TRIA01

This test is similar to CAR101, but uses CEA’s triangular element TRIA. Results are similar to those for the CAR1 element and in very good agreement with the reference.

Q92G01

This test is similar to CAR101, but uses JRC’s 9-node parabolic under-integrated quadrilateral element Q92. When run with the same boundary conditions as CAR101 (i.e. imposed vertical velocities in nodes 1, 2, 3, 5, 6 and 7), this calculation shows a sort of mechanism-like (hourglass) pattern as soon as the longitudinal strain exceeds about 30 %. However, this is unlikely to be a real hourglassing problem (although this element is under-integrated) because also the Q93 element (fully integrated) exhibits a similar behaviour (see below).

Some additional tests revealed that the problem shows up also with other materials (e.g. VM23) and therefore it is a problem of the element, and not of the VPJC material. The test was even run with PLEXIS-3C (one of EPX ancestors, 1999 version) and showed the same behaviour.

In order to eliminate the mechanism-like motions, additional constraints have been imposed (the “G” in the test name stays for “guided”) by means of the **RELA EGAL** directive: one relation imposes that the x -displacement of nodes 1, 7 and 8 be equal, and another equality relation is imposed for the x -displacement of nodes 3, 4 and 5.

With these additional constraints the result is in very good agreement with the analytical solution.

Q93G01

This test is similar to Q92G01, but uses JRC’s 9-node parabolic fully-integrated quadrilateral element Q93. The same additional constraints already discussed for the previous case are necessary also for this element (Q93) despite the fact that the element is fully integrated.

With the additional constraints the result is in very good agreement with the analytical solution.

3.1.4 Calculations with 3D shells

We consider now solutions with 3D shells, see Table 3. Since the element is set to lie in the xy -plane (so that z is the “thickness” direction), the traction is directed along the (global) y axis, which coincides with the (local) y axis of the shell. Recall that for non-continuum elements (shells, plates, bars) in EPX the elemental quantities (like stresses) are expressed along the local (or convected) axes, while the nodal quantities (such as forces) are expressed along the global axes.

CQD4S3

This test is similar to CUBE02 (in 3D), but uses JRC’s quadrilateral degenerated shell element CQD4. Results are similar to those for the CUBE element and in very good agreement with the reference.

CQD3S3

This test is similar to CQD4S3, but uses JRC’s triangular degenerated shell element CQD3. Note that for this element not all results are directly comparable with those of the quadrilateral, due to the fact that the strains and stresses are expressed along a local reference frame attached to the element (and which in general rotates as the element deforms). However, those results which can be directly

Case	Mesh	ϵ_x	ϵ_y	ϵ_z	σ_y	F_y
Analytical	—	-0.54931	1.0986	-0.54931	10.116×10^8	3.3720×10^8
CQD4S3	CQD4	-0.54894	1.0986	-0.54893	10.116×10^8	3.3776×10^8
CQD3S3	CQD3	1.3541	-0.80421	-0.54819	3.6181×10^7	3.3773×10^8
CQD9G3	CQD9	-0.54894	1.0986	-0.54803	10.116×10^8	3.3776×10^8
CQD6S3	CQD6	1.3540	-0.80422	-0.54819	3.5638×10^7	3.3767×10^8
COQIS3	COQI	N/A	N/A	N/A	N/A	N/A
Q4GSS3	Q4GS	-0.54894	1.0986	-0.54025	10.116×10^8	5.8428×10^8
T3GSS3	T3GS	-0.54894	1.0986	-0.54025	10.116×10^8	5.8428×10^8
Q4GRS3	Q4GR	-0.54894	1.0986	-0.54025	10.116×10^8	5.8428×10^8
QPPSS3	QPPS	-0.54894	1.0986	-0.54025	10.116×10^8	5.8428×10^8
DKT3S3	DKT3	-0.54894	1.0986	-0.54025	10.116×10^8	5.8428×10^8
DST3S3	DST3	-0.54894	1.0986	-0.54025	10.116×10^8	5.8428×10^8

Table 3: Calculations with 3D shell elements.

compared, i.e. ϵ_z and F_y , are in very good agreement with the reference. For a detailed discussion on the transformation of results from the local to the global reference frame see Appendix A.

CQD9G3

This test is similar to CQD4S3, but uses JRC’s 9-node parabolic degenerated quadrilateral shell CQD9. Like for the parabolic continuum elements Q92 and Q93 mentioned above, this calculation suffers from mechanism-like motions which, however, can be suppressed by suitable RELA EGAL additional constraints, so as to achieve the correct results.

CQD6S3

This test is similar to CQD9G3, but uses JRC’s triangular parabolic degenerated shell element CQD6. Note that for this element not all results are directly comparable with those of the quadrilateral, due to the fact that the strains and stresses are expressed along a local reference frame attached to the element (and which in general rotates as the element deforms). However, those results which can be directly compared, i.e. ϵ_z and F_y , are in very good agreement with the reference. For a detailed discussion on the transformation of results from the local to the global reference frame see Appendix A.

COQIS3

This test is similar to CQD3S3, but uses JRC’s 3-node triangular plate/shell element COQI. This calculation shows an excessive “shrinkage” of the element as the deformation proceeds. The problem has been investigated and details are given in Appendix A below. The conclusion is that the element is limited to small strains, in particular small membrane strains, therefore it is not suited for this particular test problem. A different (small-strain) test case should be designed to check the implementation of VPJC with the COQI element.

Q4GSS3

This test is similar to CQD4S3, but uses CEA’s quadrilateral shell element Q4GS. This element still suffers from the fact that the element thickness is not updated when large membrane strains occur, as noted in reference [9]. For this reason, the driving force F_y is largely overestimated in this example. All other quantities are in good agreement with the reference.

T3GSS3

This test is similar to Q4GSS3, but uses CEA’s triangular shell element T3GS. This element still suffers from the fact that the element thickness is not updated when large membrane strains occur, as noted in reference [9]. For this reason, the driving force F_y is largely overestimated in this example. All other quantities are in good agreement with the reference.

Q4GRS3

This test is similar to QD4S3, but uses CEA’s reduced-integrated quadrilateral shell element Q4GR. This element still suffers from the fact that the element thickness is not updated when large membrane strains occur, as noted in reference [9]. For this reason, the driving force F_y is largely overestimated in this example. All other quantities are in good agreement with the reference.

QPPSS3

This test is similar to Q4GSS3, but uses CEA’s quadrilateral shell element QPPS. This element still suffers from the fact that the element thickness is not updated when large membrane strains occur, as noted in reference [9]. For this reason, the driving force F_y is largely overestimated in this example. All other quantities are in good agreement with the reference.

DKT3S3

This test is similar to T3GSS3, but uses CEA’s discrete-Kirchhoff triangular shell element DKT3. This element still suffers from the fact that the element thickness is not updated when large membrane strains occur, as noted in reference [9]. For this reason, the driving force F_y is largely overestimated in this example. All other quantities are in good agreement with the reference.

DST3S3

This test is similar to T3GSS3, but uses CEA’s triangular shell element DST3. This element still suffers from the fact that the element thickness is not updated when large membrane strains occur, as noted in reference [9]. For this reason, the driving force F_y is largely overestimated in this example. All other quantities are in good agreement with the reference.

3.1.5 Calculations with beam/bar elements

Solutions with beam/bar elements are also obtained, according to Table 4. In this case we choose to align the element along the y global axis. Therefore, as it concerns nodal forces and other nodal quantities, the component to be considered is along y so that one should take F_y . However, for the rule stated above, the “longitudinal” stress to be considered is now σ_x .

Case	Mesh	ϵ_x	ϵ_y	ϵ_z	σ_x	F_y
Analytical	—	1.0986	−0.54931	−0.54931	10.116×10^8	3.3720×10^8
ED0101	ED01	1.0986	−0.54849	−0.54849	10.116×10^8	3.3776×10^8
FUVP01	FUN3	1.0986	−0.54849	−0.54849	10.116×10^8	3.3776×10^8
FUVP02	FUN2	1.0986	−0.54849	−0.54849	10.116×10^8	3.3776×10^8

Table 4: Calculations with beam/bar elements.

ED0101

This test is in 2D plane stress conditions (CPLA) and uses JRC’s beam element ED01. Results are in very good agreement with the reference.

FUVP01

This test is in 3D and uses JRC’s bar element FUN3. Results are in very good agreement with the reference.

FUVP02

This test is in 2D and uses JRC’s bar element FUN2. Results are in very good agreement with the reference.

3.2 Uniaxial tests at constant strain rate

Next, a similar series of tests is performed by including the effect of strain rate on the material. For simplicity, the tests are conducted at constant strain rate, a situation in which it is still easy to find an analytical solution to the problem, against which the numerical results can then be compared. To find the reference solution we proceed as follows.

3.2.1 Stress

We assume a static (or quasi-static) uniaxial test along z so that the lateral stresses in the “specimen” (initially a regular unit cube, see Figure 1) along x and y can be neglected. Since no shear stresses are present, the only non-zero stress is the longitudinal stress σ_z .

3.2.2 Strain

As concerns the strains, again the shear components are all null. The longitudinal strain e_z is the one imposed by the driven longitudinal displacement (or velocity) while the lateral strains, in the two normal directions, are equal ($e_x = e_y$) and can be computed as follows.

Since the test involves large strains we use the (natural, or logarithmic) strain, denoted by the symbol e , as opposed to the engineering strain, which is denoted ϵ . The Cauchy (or true) stress is indicated by σ . We have, for the longitudinal strain:

$$e_z = \ln \frac{L_z}{L_{z0}} \quad (15)$$

where L_z is the current length and L_{z0} is the initial length of the specimen along z . The strain can be separated into an elastic and a plastic part:

$$e_z = e_z^{\text{el}} + e_z^{\text{pl}} \quad (16)$$

If σ_z denotes the longitudinal stress, and σ_x, σ_y are the lateral stresses, which are null by assumption, then the longitudinal elastic strain is given by:

$$e_z^{\text{el}} = \sigma_z / E \quad (17)$$

where E is Young’s modulus of the material, while the lateral elastic strains are:

$$e_x^{\text{el}} = e_y^{\text{el}} = -\frac{\nu}{E} \sigma_z = -\nu e_z^{\text{el}} \quad (18)$$

where ν is Poisson’s coefficient of the material. The lateral plastic strains can be obtained from the assumption, which is usually adopted in plasticity, that the plastic deformations are incompressible, i.e. occur without change of volume:

$$e_x^{\text{pl}} + e_y^{\text{pl}} + e_z^{\text{pl}} = 0 \quad (19)$$

Since by symmetry it must be $e_x^{\text{pl}} = e_y^{\text{pl}}$ we obtain from (19):

$$e_x^{\text{pl}} = e_y^{\text{pl}} = -\frac{1}{2} e_z^{\text{pl}} \quad (20)$$

Finally, from (18) and (20) the total lateral strains result in:

$$e_x = e_y = -\frac{\nu}{E} \sigma_z - \frac{1}{2} \left(e_z - \frac{\sigma_z}{E} \right) \quad (21)$$

3.2.3 Strain rate

If the test is conducted at constant (natural) equivalent plastic strain rate, then the longitudinal plastic strain varies in time t according to the expression:

$$e_z^{\text{pl}}(t) = kt \quad (22)$$

where

$$k = \frac{de_z^{\text{pl}}}{dt} = \frac{e_z^{\text{pl}}}{t} \quad (23)$$

is the (longitudinal) plastic strain rate, usually expressed in s^{-1} .

3.2.4 Equivalent stress

The equivalent stress σ_{eq} according to von Mises (which is used e.g. in the temperature softening term as well as in the yield function) is defined as:

$$\sigma_{\text{eq}} = \sqrt{3J_2} = \sqrt{\frac{3}{2}s_{ij}s_{ij}} \quad (24)$$

where

$$J_2 = \frac{1}{2}s_{ij}s_{ij} \quad (25)$$

is the second invariant of the deviatoric stress tensor s_{ij}

$$s_{ij} = \sigma_{ij} - \frac{1}{3}\sigma_{kk}\delta_{ij} \quad (26)$$

with δ_{ij} Kronecker's delta and with Einstein's summation convention on repeated indices. By expanding (24) in terms of the stress components one obtains:

$$\sigma_{\text{eq}} = \sqrt{\frac{1}{2}[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2] + 3\tau_{xy}^2 + 3\tau_{yz}^2 + 3\tau_{zx}^2} \quad (27)$$

In the uniaxial stress test considered here the only non-zero stress component is the longitudinal stress σ_z so that (27) reduces to:

$$\sigma_{\text{eq}} = \sigma_z \quad (28)$$

as it is obvious.

3.2.5 Equivalent plastic strain

The equivalent (or cumulated) plastic strain, indicated by \bar{e}^{pl} or p , is the energy-conjugated variable to the equivalent stress and is defined (incrementally) as:

$$d\bar{e}^{\text{pl}} = dp = \sqrt{\frac{2}{3}de_{ij}^{\text{pl}}de_{ij}^{\text{pl}}} \quad (29)$$

From (20) we have, in a uniaxial stress test:

$$\begin{aligned} de_x^{\text{pl}} &= de_y^{\text{pl}} = -\frac{1}{2}de_z^{\text{pl}} \\ de_{xy}^{\text{pl}} &= de_{yz}^{\text{pl}} = de_{xz}^{\text{pl}} = 0 \end{aligned} \quad (30)$$

so that from (29) we get:

$$\begin{aligned}
dp &= \sqrt{\frac{2}{3} \left[\left(de_x^{\text{pl}} \right)^2 + \left(de_y^{\text{pl}} \right)^2 + \left(de_z^{\text{pl}} \right)^2 \right]} \\
&= \sqrt{\frac{2}{3} \left[\frac{\left(de_z^{\text{pl}} \right)^2}{4} + \frac{\left(de_z^{\text{pl}} \right)^2}{4} + \left(de_z^{\text{pl}} \right)^2 \right]} \\
&= \sqrt{\frac{2}{3} \frac{6}{4} \left(de_z^{\text{pl}} \right)^2} \\
&= de_z^{\text{pl}}
\end{aligned} \tag{31}$$

By integrating this in time we obtain:

$$p = e_z^{\text{pl}} \tag{32}$$

i.e., the equivalent plastic strain coincides with the longitudinal plastic strain, as it seems obvious in a uniaxial stress test.

3.2.6 Relative displacement

The numerical test will be displacement-driven. Therefore, we need to determine the expression in time of the (relative) displacement $d(t)$ of the two extremities of the specimen which should be used to generate the desired plastic strain rate, i.e. a constant value k in the present example:

$$p = kt \tag{33}$$

or, equivalently

$$\dot{p} = k \tag{34}$$

If one would neglect the elastic part of the longitudinal strain e_z^{el} compared with the plastic part e_z^{pl} , which for large strains is much larger ($e_z^{\text{pl}} \gg e_z^{\text{el}}$), one would obtain simply

$$e_z = \ln \frac{L}{L_0} = e_z^{\text{el}} + e_z^{\text{pl}} \approx e_z^{\text{pl}} = p = kt \tag{35}$$

and from this

$$L = L_0 \exp(kt) \tag{36}$$

so that the displacement would result in

$$d(t) = L(t) - L_0 = L_0 [\exp(kt) - 1] \tag{37}$$

By including also the elastic contribution, we obtain instead:

$$e_z = \ln \frac{L}{L_0} = e_z^{\text{el}} + e_z^{\text{pl}} = \frac{\sigma_z}{E} + kt \tag{38}$$

where σ_z is the longitudinal stress, E is Young's modulus and σ_z/E is the elastic longitudinal strain in the assumed uniaxial stress test. Then, instead of (36)

$$L = L_0 \exp \left(\frac{\sigma_z}{E} + kt \right) \tag{39}$$

and in place of (37)

$$d(t) = L(t) - L_0 = L_0 \left[\exp \left(\frac{\sigma_z}{E} + kt \right) - 1 \right] \tag{40}$$

One sees that the traction test should be subdivided in two phases. The first phase is purely elastic while the second phase is elasto-plastic. During the elastic phase the length of the specimen passes from the initial value L_0 (unloaded specimen) to the value L_{el} at which the longitudinal strain (which is still purely elastic) reaches the elastic limit

$$e_z^{\text{el}} = \frac{A}{E} \quad (41)$$

and the longitudinal stress is

$$\sigma_z = A \quad (42)$$

so that

$$L_{\text{el}} = L_0 \exp\left(\frac{A}{E}\right) \quad (43)$$

During this phase, the displacement is governed by an expression similar to (40) but without the term kt , i.e.

$$d_{\text{el}}(t) = L_{\text{el}}(t) - L_0 = L_0 \left[\exp\left(\frac{\sigma_z}{E}\right) - 1 \right] \quad (44)$$

This is because the model (elasto-viscoplastic) includes viscosity only in the plastic part of the deformation, as it can be seen from (1) where the plastic strain rate \dot{p} (not the total strain rate) appears in the strain-rate hardening term $(1 + \dot{p}^*)^C$.

From this instant on, as the longitudinal strain is increased some plasticity starts to occur. Therefore one sees that, in order to use the expression (40), the time origin must be set so that $t = 0$ when the elastic limit is reached. Then, for convenience, the numerical test will be started at a suitable negative time.

With this convention, the two expressions (40) for the elastic phase and (44) for the elastoplastic phase may be combined into a single expression

$$d(t) = L(t) - L_0 = L_0 \left\{ \exp\left[\frac{\sigma_z}{E} + \max(kt, 0)\right] - 1 \right\} \quad (45)$$

which is valid through the entire uniaxial traction test.

In order to use (45) to pilot the displacement in the numerical test, the quantity σ_z must be explicited in terms of other (known) quantities. To this end, one may note that during the elasto-plastic phase of the uniaxial traction test considered here (which is done at constant equivalent plastic strain rate and without temperature softening effects), the longitudinal stress σ_z is constantly equal to the current yield stress

$$\sigma_z = \sigma_Y \quad (46)$$

By using (1), in the present case ($m = 0$) this reduces to

$$\sigma_z = \sigma_Y = [A + Q_1 (1 - e^{-C_1 p}) + Q_2 (1 - e^{-C_2 p})] (1 + \dot{p}^*)^C \quad (47)$$

or, by using (33) and (34) and by recalling that $\dot{p}^* = \dot{p}/p_0$

$$\sigma_z(t) = \sigma_Y(t) = \left[A + Q_1 (1 - e^{-C_1 kt}) + Q_2 (1 - e^{-C_2 kt}) \right] \left(1 + \frac{k}{\dot{p}_0} \right)^C \quad (48)$$

3.2.7 Choice of the test parameters

We want to choose the test parameters so that a longitudinal natural plastic strain of 100 % is reached in 2 s, at a constant rate. From (23) and (32) the equivalent plastic strain rate k results in:

$$k = \frac{e_z^{\text{pl}}}{t} = \frac{p}{t} = \frac{1}{2} \quad (49)$$

From this we obtain for the equivalent plastic strain:

$$p = \frac{t}{2} \quad (50)$$

and for the equivalent plastic strain rate:

$$\dot{p} = \frac{1}{2} = \text{const.} \quad (51)$$

By combining (32), (16) and (17) we obtain:

$$e_z = e_z^{\text{el}} + e_z^{\text{pl}} = \frac{\sigma_z}{E} + \frac{t}{2} \quad (52)$$

For simplicity, we do not want to consider the temperature softening effect in this test. To this end, we set the exponent m to the special value $m = 0$. In this case by convention the code assumes $T^{*m} = 0$ and therefore the temperature term becomes $(1 - T^{*m}) = (1 - 0) = 1$, thus in practice disabling temperature softening. Note also that in this case the code does not update the temperature, so that it remains at the initial (room) value T_r .

With these settings, the expression (48) of the longitudinal stress (valid for $t > 0$) becomes

$$\sigma_z(t) = \left\{ A + Q_1 \left[1 - \exp \left(-\frac{C_1}{2} t \right) \right] + Q_2 \left[1 - \exp \left(-\frac{C_2}{2} t \right) \right] \right\} \left(1 + \frac{1}{2\dot{p}_0} \right)^C \quad (53)$$

One last parameter to be chosen is the duration of the elastic phase t_{el} . In fact, the initial time of the numerical test will be set to $t_0 = -t_{\text{el}}$ and the final time will be set to $t_1 = 2$ s. In this way, as already mentioned, the elastic limit will be reached at $t = 0$. The choice of t_{el} , therefore, determines the rate at which loading occurs during the elastic phase.

In principle the behaviour of the material during the elastic phase is independent of the rate of loading. However, this is valid only in an ideal static case. If loading would be too rapid, then non-negligible lateral stresses would build up due to lateral inertia in the specimen, producing oscillations and a multi-axial stress state instead of the purely uniaxial stress state assumed in the test specifications.

In order to try avoid such phenomena, the loading rate during the first (elastic) phase is chosen such that the (elastic) longitudinal strain rate \dot{e}_z^{el} is constant and equals the chosen equivalent plastic strain rate k during the second (elasto-plastic) phase

$$\dot{e}_z^{\text{el}} = k \quad (54)$$

Since the longitudinal strain at the elastic limit e_z^{el} is given by (41), we obtain for t_{el} :

$$t_{\text{el}} = \frac{e_z^{\text{el}}}{\dot{e}_z^{\text{el}}} = \frac{e_z^{\text{el}}}{k} = \frac{A}{Ek} \quad (55)$$

i.e., in this case

$$t_{\text{el}} = \frac{2A}{E} \quad (56)$$

The displacement during the elastic phase is obtained from (54) as follows:

$$\begin{aligned}
d_{\text{el}}(t) &= L_{\text{el}} - L_0 \\
&= L_0 \exp(e_z^{\text{el}}) - L_0 \\
&= L_0 \left[\exp(e_z^{\text{el}}) - 1 \right] \\
&= L_0 \left\{ \exp \left[\dot{e}_z^{\text{el}}(t - t_0) \right] - 1 \right\} \\
&= L_0 \{ \exp [k(t - t_0)] - 1 \}
\end{aligned} \tag{57}$$

3.2.8 Analytical solution

The analytical value of the longitudinal stress σ_z at the final time $t = 2$ s, at which a longitudinal plastic strain of 100 % is reached, can be obtained from (48) by using the values of the material constants given in (10), the value of k given by (49) and the following values of \dot{p}_0 and C :

$$\begin{aligned}
\dot{p}_0 &= 5.0 \times 10^{-4} \\
C &= 0.01
\end{aligned} \tag{58}$$

resulting in:

$$\sigma_z(2.0) = \sigma_Y(2.0) = 1.08221 \times 10^9 \tag{59}$$

By assuming for the elastic constants of the material the following values:

$$\begin{aligned}
E &= 2.1 \times 10^{11} \\
\nu &= 0.33
\end{aligned} \tag{60}$$

the final longitudinal elastic strain can be computed from (17)

$$e_z^{\text{el}}(2.0) = \sigma_z(2.0)/E = 1.08221 \times 10^9 / 2.1 \times 10^{11} = 5.15338 \times 10^{-3} \tag{61}$$

while the final longitudinal plastic strain is given by (22) and results in:

$$e_z^{\text{pl}}(2.0) = 2.0k = 1.0 \tag{62}$$

so that the final longitudinal total strain is:

$$e_z(2.0) = e_z^{\text{el}}(2.0) + e_z^{\text{pl}}(2.0) = 5.15338 \times 10^{-3} + 1.0 = 1.00515 \tag{63}$$

The final lateral strains can be computed from (21)

$$e_x(2.0) = e_y(2.0) = -\frac{\nu}{E}\sigma_z - \frac{1}{2}\left(e_z - \frac{\sigma_z}{E}\right) = -0.501701 \tag{64}$$

The final cross section of the specimen is

$$S(2.0) = L_y L_z = 1.0 \exp(e_x) \cdot 1.0 \exp(e_y) = 0.605500 \cdot 0.605500 = 0.366630 \tag{65}$$

and the final longitudinal force is

$$F_z(2.0) = S\sigma_z = 0.366630 \cdot 1.08221 \times 10^9 = 3.96771 \times 10^8 \tag{66}$$

Case	Mesh	ϵ_x	ϵ_y	ϵ_z	σ_z	F_z
Analytical	—	-0.50170	-0.50170	1.0052	10.822×10^8	3.9677×10^8
CUBE05	CUBE	-0.50169	-0.50169	1.0051	10.821×10^8	3.9675×10^8

Table 5: Calculations with 3D continuum elements.

3.2.9 Calculations with 3D continuum elements

The calculations performed by EPX with constant strain rate are summarized in Table 5.

CUBE05

The test CUBE05 uses a unit hexahedron (CUBE element) with the JAUM option. This option is necessary with some CEA's continuum elements (e.g. CUBE) in order to activate large strain computation with Jaumann stress rate (the option is not needed with JRC's continuum elements).

The input file is listed and commented below:

```
CUBE05
ECHO
!CONV WIN
LAGR TRID
DIME TTHI 50101 MNTI 701 TERM
```

Some dimensioning is needed due to the large number of time points in tables (TTHI) and of prescribed output time steps (MNTI), see [1].

```
GEOM LIBR POIN 8 CUBE 1 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 0.5 -0.5 0.5 0.5
1 2 3 4 5 6 7 8
```

The material is VPJC with the material parameters given by (10) and (58).

```
MATE VPJC RO 7850.0 ! Docol 600 steel parameters
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 1.E-2 ! This is 1.E-3 in Table 1 of material parameters (?)
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! M = 0 : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
```

Note that, as concerns the material parameter C (strain-rate hardening parameter C) used in the input data set, values $C = 0.01$, $C = 0.005$ and $C = 0.001$ are found in the literature. It is reasonable to use $C = 0.01$ in this report since the scope here is to show that the routine gives acceptable results, rather than to obtain a perfect match to some experimental data.

The relative displacements history $d(t)$ is read from an external file (see below) for convenience, since it contains 50,101 time points:

```
INCLUDE 'fonc_disp.txt'
```

The displacement is imposed along the vertical direction (z), half of it to the lower face and half of it to the upper face of the cube:

```
LINK COUP
DEPL 3 -0.5 FONC 1 LECT 1 2 3 4 TERM
DEPL 3 0.5 FONC 1 LECT 5 6 7 8 TERM
```

The results are printed at every step initially (up to step 201) and then every 100 steps:

```
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO EPST
NUPA LECT 0 PAS 1 201 PAS 100 50101 TERM
FICH ALIC
NUPA LECT 0 PAS 1 201 PAS 100 50101 TERM
```

The user-defined step is chosen (PAS UTIL) and the JAUM option is set for CUBE:

OPTI NOTE PAS UTIL LOG 100
JAUM

The initial (negative) and final times are set, and the time step is entirely piloted by prescribing all the time instants at which the solution will be computed (HIST), in this case 50,100 time instants, which are conveniently specified by the PROG directive. Note that the initial time instant must not be included (it is commented out).

```

CALC TINI -3.523809523809524E-03
TEND 2.D0
HIST PROG
!-3.523809523809524E-03
-3.488571428571429E-03
-3.453333333333333E-03
-3.418095238095238E-03
-3.382857142857143E-03
-3.347619047619048E-03
-3.312380952380953E-03
-3.277142857142858E-03
-3.241904761904763E-03
-3.206666666666668E-03
-3.171428571428572E-03
-3.136190476190477E-03
-3.100952380952382E-03
-3.065714285714287E-03
-3.030476190476192E-03
-2.995238095238097E-03
-2.960000000000002E-03
-2.924761904761907E-03
-2.889523809523811E-03
-2.854285714285716E-03
-2.819047619047621E-03
-2.783809523809526E-03
-2.748571428571431E-03
-2.713333333333336E-03
-2.678095238095241E-03
-2.642857142857146E-03
-2.607619047619050E-03
-2.572380952380955E-03
-2.537142857142860E-03
-2.501904761904765E-03
-2.466666666666667E-03
-2.431428571428575E-03
-2.396190476190480E-03
-2.360952380952385E-03
-2.325714285714289E-03
-2.290476190476194E-03
-2.255238095238099E-03
-2.220000000000004E-03
-2.184761904761909E-03
-2.149523809523814E-03
-2.114285714285719E-03
-2.079047619047624E-03
-2.043809523809528E-03
-2.008571428571433E-03
-1.973333333333338E-03
-1.938095238095243E-03
-1.902857142857148E-03
-1.867619047619052E-03
-1.832380952380957E-03
-1.797142857142862E-03
-1.761904761904766E-03
-1.726666666666671E-03
-1.691428571428575E-03
-1.656190476190480E-03
-1.620952380952385E-03
-1.585714285714289E-03
-1.550476190476194E-03
-1.515238095238099E-03
-1.480000000000003E-03
-1.444761904761908E-03
-1.409523809523813E-03
-1.374285714285717E-03
-1.339047619047622E-03
-1.303809523809527E-03
-1.268571428571431E-03
-1.233333333333336E-03
-1.198095238095241E-03
-1.162857142857145E-03
-1.127619047619050E-03
-1.092380952380955E-03
-1.057142857142859E-03
-1.021904761904764E-03
-9.866666666666687E-04
-9.514285714285734E-04
-9.161904761904782E-04
-8.809523809523830E-04
-8.457142857142877E-04
-8.104761904761925E-04
-7.752380952380973E-04
-7.400000000000020E-04
-7.047619047619068E-04
-6.695238095238116E-04
-6.342857142857164E-04
-5.990476190476211E-04
-5.638095238095259E-04
-5.285714285714307E-04
-4.933333333333354E-04
-4.580952380952402E-04
-4.228571428571450E-04
-3.876190476190497E-04
-3.523809523809545E-04
-3.171428571428593E-04
-2.819047619047640E-04
-2.466666666666688E-04
-2.114285714285736E-04
-1.761904761904783E-04
-1.409523809523831E-04
-1.057142857142879E-04
-7.047619047619263E-05
-3.523809523809739E-05
0.000000000000000E+00
PAS 4.D-5 2.D0 TERM
FIN

```

The imposed displacement is computed by a small ad-hoc Fortran program displ.f, which implements the formulas presented above.

displ.f

```

PROGRAM displ
IMPLICIT NONE
REAL(8) :: e, a, q1, c1, q2, c2, pdot0, c, k, m
REAL(8) :: l0, dt, t2, l, t, t0, tel, dtel, d
REAL(8) :: pdotstar, b, f1, f2, sz
INTEGER :: nel, n, i
*
e = 2.1D11
a = 3.70D8
q1 = 2.364D8
c1 = 39.3D0
q2 = 4.081D8
c2 = 4.5D0
pdot0 = 5.D-4
c = 1.D-2
k = 0.5D0
m = 0.D0
l0 = 1.D0
dt = 4.D-5
t2 = 2.D0
nel = 100
*
tel = 2.D0*a / e
dtel = tel / nel
*
t0 = -tel
t = t0
d = 0.D0
write (6,1) t, d
1 FORMAT (1P,2E23.15)
DO i = 1, nel
IF (i < nel) THEN
t = t + dtel
ELSE
t = 0.D0
ENDIF
d = 10*(exp(k*(t-t0)) - 1.D0)
write (6,1) t, d
END DO
*
n = NINT (t2 / dt)
pdotstar = k / pdot0
b = (1.D0 + pdotstar)**c
DO i = 1, n
t = dt*i
f1 = q1*(1.D0 - exp(-c1*k*t))
f2 = q2*(1.D0 - exp(-c2*k*t))
sz = (a + f1 + f2)*b
d = 10*(exp(sz/e + k*t) - 1.D0)
write (6,1) t, d
END DO
*
END PROGRAM displ

```

The output of the program is piped onto file `fonc_disp.txt`. At the beginning of this file we insert one line which starts the **FONC** directive, declaring one “table” function with 50,101 points:

```
FONC 1 TABL 50101
```

Next come 50,101 lines (generated by the Fortran program) containing each one a couple of values $t, d(t)$. At the end of the file we insert the line:

```
RETURN
```

This instructs EPX to continue reading from the main EPX input file.

The stress along z is computed by a small ad-hoc Fortran program `sigma.f`, which implements the formulas presented above.

`sigma.f`

```
PROGRAM sigma
IMPLICIT NONE
REAL(8) :: e, a, q1, c1, q2, c2, pdot0, c, k, m
REAL(8) :: l0, dt, t2, l, t, t0, tel, dtel, d
REAL(8) :: pdotstar, b, f1, f2, ez, sz
INTEGER :: nel, n, i, ntot

*
e      = 2.1D11
a      = 3.70D8
q1     = 2.364D8
c1     = 39.3D0
q2     = 4.081D8
c2     = 4.5D0
pdot0  = 5.D-4
c      = 1.D-2
k      = 0.5D0
m      = 0.D0
l0     = 1.D0
dt     = 4.D-5
t2     = 2.D0
nel    = 100

*
tel = 2.D0*a / e
dtel = tel / nel

*
t0 = -tel
t = t0
sz = 0.D0
n = NINT (t2 / dt)

ntot = nel + n + 1
write (6,2) ntot
2 FORMAT ('VALUES',I6,' COMPONENTS 1',/,
>      '* Time [s] STRESS [PA]',/,
>      '* T sz')
write (6,1) t, sz
1 FORMAT (1P,2E17.6)
DO i = 1, nel
  IF (i < nel) THEN
    t = t + dtel
  ELSE
    t = 0.D0
  ENDIF
  d = l0*(exp(k*(t-t0)) - 1.D0)
  ez = LOG ((l0+d) / l0)
  sz = e*ez
  write (6,1) t, sz
END DO

*
pdotstar = k / pdot0
b = (1.D0 + pdotstar)**c
DO i = 1, n
  t = dt*i
  f1 = q1*(1.D0 - exp(-c1*k*t))
  f2 = q2*(1.D0 - exp(-c2*k*t))
  sz = (a + f1 + f2)*b
  d = l0*(exp(sz/e + k*t) - 1.D0)
  write (6,1) t, sz
END DO

*
END PROGRAM sigma
```

The output of the program is piped onto file `sigma.pun`, which is written in EPX’s `.PUN` format. This format is the one produced by EPX by means of the **LIST** command, and can be used to enter in EPX a set of external data (in tabular form) to be plotted for comparison with EPX’s own solution.

Some results are shown in Figure 3: the displacements, the cross-section area, the total strains, the stresses, the nodal forces and the stress *vs.* strain curve. The agreement with the analytical solution at the final time is very good, as shown also in Table 5. Some small oscillations in the numerical solution are due to dynamic effects in the lateral directions, which are left free.

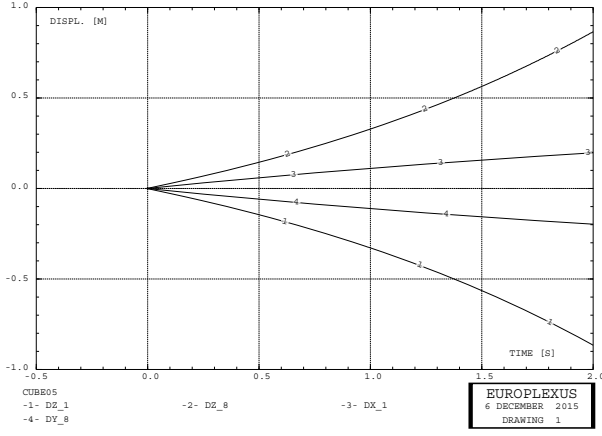
In Figure 3 (d) the computed stress (in black) is compared with the analytical result (in red) from the `sigma.pun` file obtained as explained above, showing excellent overall agreement.

When looking at results in some more detail, one sees that at the threshold between elastic and elasto-plastic behaviour (which in this test occurs at time $t = 0$ by convention, as explained in Section 3.2.6), a sudden “jump” occurs in the stresses.

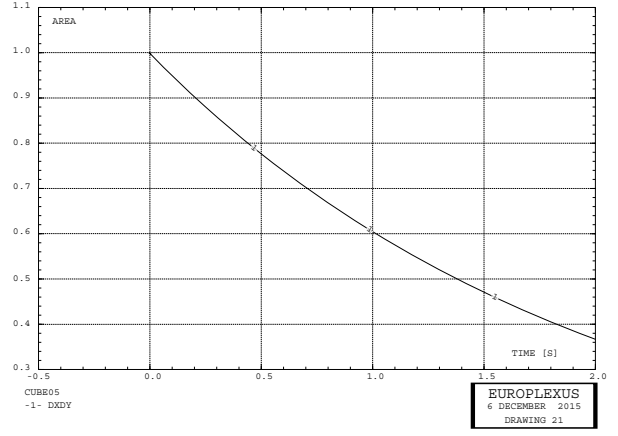
Figure 4 shows the stress along z in a small time window around $t = 0$. The black curve is the numerical result, which exhibits some oscillations. The red curve is the analytical result, i.e. the plot of the contents of file `sigma.pun` described above. Note that not only the numerical, but also the analytical solution exhibits a sudden jump at $t = 0$. The numerical model is unable to represent such a jump exactly and this explains the oscillations observed in the numerical solution.

The (analytical) discontinuity in stress is due to the fact that the model is elastic-viscoplastic. In other words, as long as the material behaves elastically, no viscous effects are included in the material law. However, as soon as some plasticity occurs, some viscosity starts to develop.

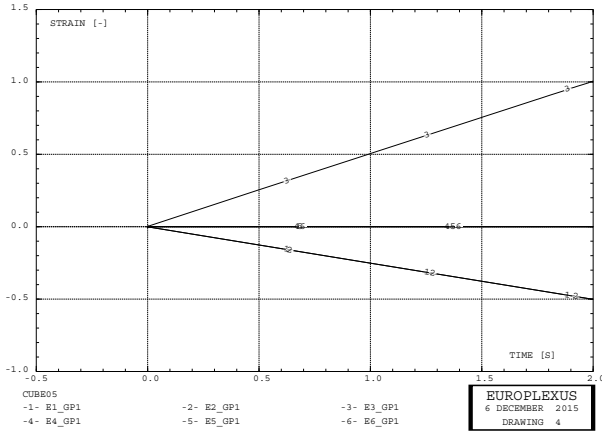
In the material law (1) viscosity is represented by the strain-rate hardening multiplicative term $\eta = (1 + \dot{p}^*)^C$, which is related to the dimensionless plastic strain rate \dot{p}^* . With the values assumed above ($\dot{p} = 0.5$, $\dot{p}_0 = 5.0 \times 10^{-4}$, $C = 0.01$), one finds $\dot{p}^* = 1000$ and then $\eta = 1.0715$. The value of η passes suddenly from 1.0 in the elastic phase to 1.0715 in the elasto-plastic phase. This corresponds precisely to the sudden increase by 7.15 % of the stress in the red curve shown in Figure 4.



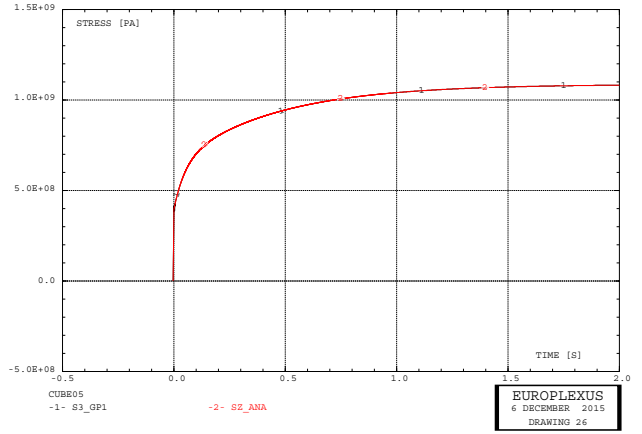
(a) Displacements



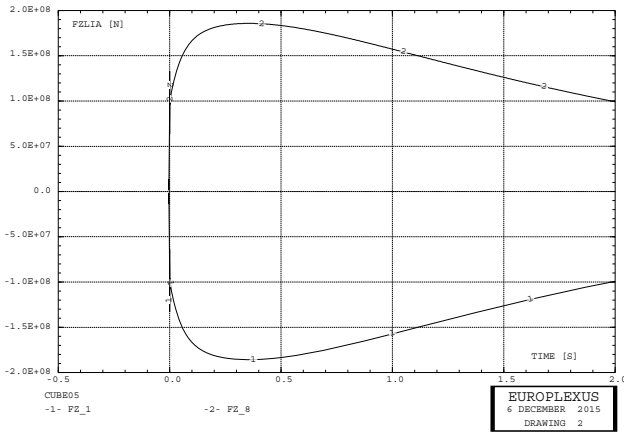
(b) Cross-section area



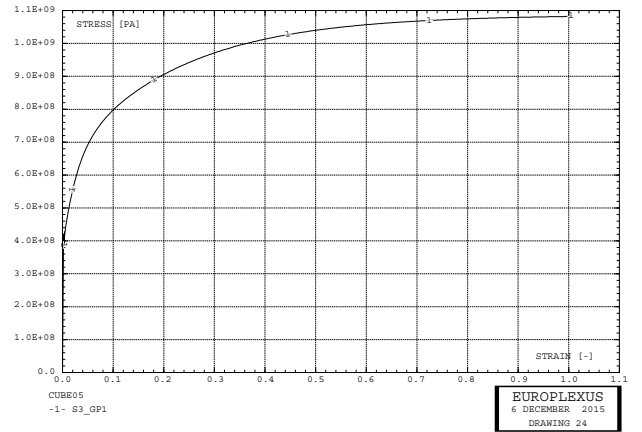
(c) Strains



(d) Stresses (comp./anal.)



(e) Nodal forces



(f) Stress vs. strain

Figure 3: Some results of test case CUBE05.

4 Conclusions and future work

The VPJC material has been tested with a large variety of finite elements in the EPX code. Overall, the models behave as expected, but there remain a few malfunctionings:

- Some shell elements of CEA (Q4GS, T3GS, Q4GR, QPPS, DKT3 and DST3) do not give the exact answer expected because the element thickness is not updated as a result of large membrane strains. However, this is a problem of the element, as already noted in [9], and not of the VPJC material. The problem has been reported to CEA and might be corrected in the near future.

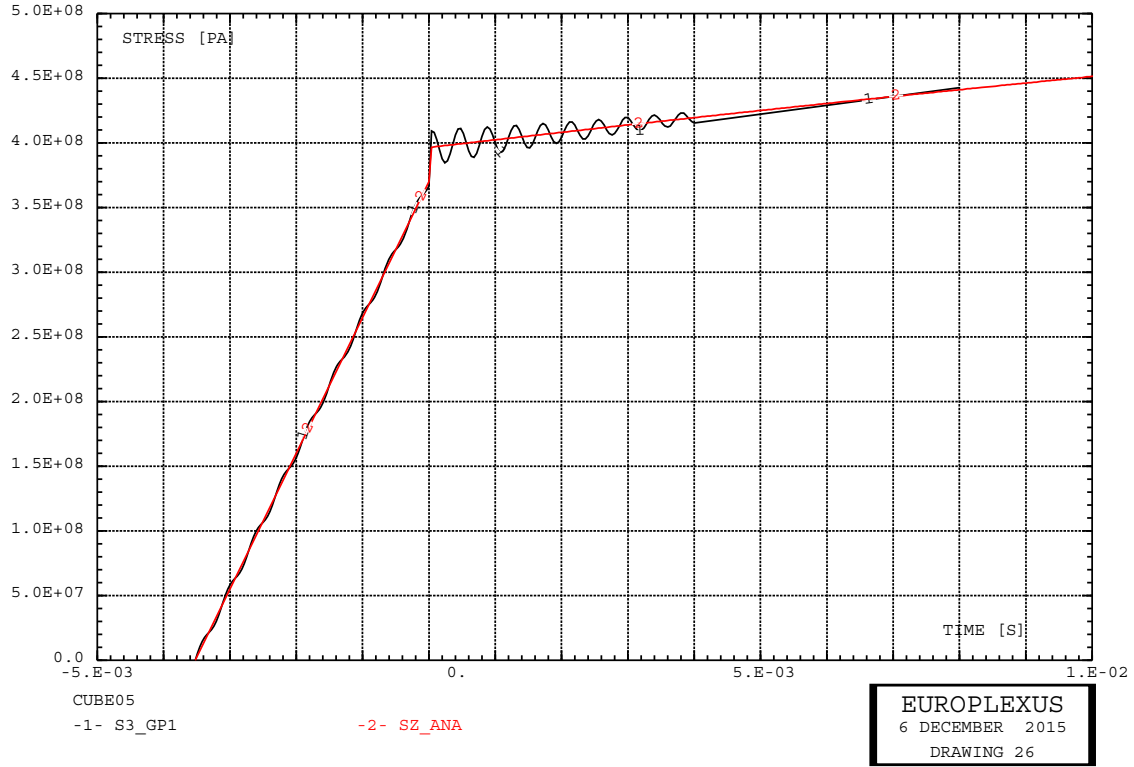


Figure 4: Stress at the onset of plasticity in case CUBE05.

- The JRC parabolic elements of the quadrilateral and cube families (C272, C273, CQD9, Q92 and Q93) suffer from mechanism-like motions if the standard boundary conditions of the large-strain test (only vertical velocities) are imposed. The mechanism can be suppressed by suitable additional constraints on the equality of some relevant displacements.
- The JRC triangular shell elements CQD3 and CQD6 give the correct nodal forces and the correct stresses (once the latter are rotated in the global system for comparison with the analytical solution). The total strains, however, are wrong even after rotation. This is not an issue in practical applications since the total strains are only a post-processing result and do not intervene in the numerical solution.
- The COQI element is not designed to undergo large strains, in particular large membrane strains, such as those encountered in the test cases considered above. Therefore, a specif (small strain) test should be designed to check this element in conjunction with the VPJC material.

The tests performed so far verify only pure (uniaxial) traction loading situations, without and with strain rate (viscous) effects. The temperature effect ($m \neq 0$) has not been investigated. Furthermore, element failure and/or melting due to temperature effect has not been tested yet. Single element testing in rate-independent simple shear, uniaxial tension and simple shear at elevated strain rates, temperature softening and element failure are treated in [3].

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Appendix A — Coordinate transformations

This Section recalls the coordinate transformations needed to interpret the results from triangular elements. Although the elements considered here (COQI, CQD3, CQD6) are 3D, the numerical examples considered in the previous Sections are such that the elements lie in the XY plane of the global reference, and the loading is such that the deformation occurs in the element's plane.

Therefore, for simplicity, the Z direction can be ignored and the transformations are carried out in 2D space.

Transformation of a vector

Let $\mathbf{v} = [v_X, v_Y]^T$ be a vector in 2D space, referred to the (global) coordinate system X, Y . Consider a second (rotated) reference frame x, y , obtained from X, Y upon rotation by an angle β in the anti-clockwise direction, as shown in Figure 5.

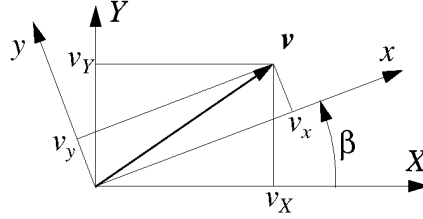


Figure 5: Vector transformation in 2D.

The expression of \mathbf{v} in the rotated reference frame is:

$$\begin{bmatrix} v_x \\ v_y \end{bmatrix} = \mathbf{R} \begin{bmatrix} v_X \\ v_Y \end{bmatrix} \quad (67)$$

where \mathbf{R} is the transformation (rotation) matrix:

$$\mathbf{R} = \begin{bmatrix} \cos \beta & \sin \beta \\ -\sin \beta & \cos \beta \end{bmatrix} \quad (68)$$

Since it represents a rigid rotation, the matrix \mathbf{R} is orthogonal:

$$\mathbf{R}^{-1} = \mathbf{R}^T \quad (69)$$

and therefore the inverse transformation, from the rotated to the global reference, is:

$$\begin{bmatrix} v_X \\ v_Y \end{bmatrix} = \mathbf{R}^{-1} \begin{bmatrix} v_x \\ v_y \end{bmatrix} = \mathbf{R}^T \begin{bmatrix} v_x \\ v_y \end{bmatrix} = \begin{bmatrix} \cos \beta & -\sin \beta \\ \sin \beta & \cos \beta \end{bmatrix} \begin{bmatrix} v_x \\ v_y \end{bmatrix} \quad (70)$$

Transformation of a tensor

A tensor such as the stress $\boldsymbol{\sigma}$ (or the strain $\boldsymbol{\epsilon}$) transforms according to:

$$\begin{bmatrix} \sigma_x & \tau_{xy} \\ \tau_{xy} & \sigma_y \end{bmatrix} = \mathbf{R} \begin{bmatrix} \sigma_X & \tau_{XY} \\ \tau_{XY} & \sigma_Y \end{bmatrix} \mathbf{R}^T \quad (71)$$

where the notation σ_X has been used instead of σ_{XX} for simplicity and, as concerns the shear components, $\tau_{XY} = \tau_{YX}$ for reciprocity.

By developing (71) one obtains:

$$\begin{aligned} \sigma_x &= \cos^2 \beta \sigma_X + 2 \sin \beta \cos \beta \tau_{XY} + \sin^2 \beta \sigma_Y \\ \tau_{xy} &= -\sin \beta \cos \beta \sigma_X + (\cos^2 \beta - \sin^2 \beta) \tau_{XY} + \sin \beta \cos \beta \sigma_Y \\ \sigma_y &= \sin^2 \beta \sigma_X - 2 \sin \beta \cos \beta \tau_{XY} + \cos^2 \beta \sigma_Y \end{aligned} \quad (72)$$

The inverse transformation of stress, from the rotated to the global reference, is:

$$\begin{bmatrix} \sigma_X & \tau_{XY} \\ \tau_{XY} & \sigma_Y \end{bmatrix} = \mathbf{R}^T \begin{bmatrix} \sigma_x & \tau_{xy} \\ \tau_{xy} & \sigma_y \end{bmatrix} \mathbf{R} \quad (73)$$

which, upon development, gives:

$$\begin{aligned} \sigma_X &= \cos^2 \beta \sigma_x - 2 \sin \beta \cos \beta \tau_{xy} + \sin^2 \beta \sigma_y \\ \tau_{XY} &= \sin \beta \cos \beta \sigma_x + (\cos^2 \beta - \sin^2 \beta) \tau_{xy} - \sin \beta \cos \beta \sigma_y \\ \sigma_Y &= \sin^2 \beta \sigma_x + 2 \sin \beta \cos \beta \tau_{xy} + \cos^2 \beta \sigma_y \end{aligned} \quad (74)$$

Note that, of course, (74) can also be obtained directly from (72) by replacing the angle β with $-\beta$ and by noting that:

$$\begin{aligned} \sin(-\beta) &= -\sin \beta \\ \cos(-\beta) &= \cos \beta \\ \sin^2(-\beta) &= \sin^2 \beta \\ \cos^2(-\beta) &= \cos^2 \beta \\ \sin(-\beta) \cos(-\beta) &= -\sin \beta \cos \beta \end{aligned} \quad (75)$$

The above equations (71–74) can also be used to transform the strain tensor ϵ . However, if one uses the engineering shear strain γ_{xy} instead of the tensor shear strain ϵ_{xy} (as it is the case in EPX), one must take into account the fact that $\gamma_{xy} = 2\epsilon_{xy}$, so that the transformation equations become, respectively:

$$\begin{bmatrix} \epsilon_x & \gamma_{xy}/2 \\ \gamma_{xy}/2 & \epsilon_y \end{bmatrix} = \mathbf{R} \begin{bmatrix} \epsilon_X & \gamma_{XY}/2 \\ \gamma_{XY}/2 & \epsilon_Y \end{bmatrix} \mathbf{R}^T \quad (76)$$

$$\begin{aligned} \epsilon_x &= \cos^2 \beta \epsilon_X + \sin \beta \cos \beta \gamma_{XY} + \sin^2 \beta \epsilon_Y \\ \gamma_{xy} &= -2 \sin \beta \cos \beta \epsilon_X + (\cos^2 \beta - \sin^2 \beta) \gamma_{XY} + 2 \sin \beta \cos \beta \epsilon_Y \\ \epsilon_y &= \sin^2 \beta \epsilon_X - \sin \beta \cos \beta \gamma_{XY} + \cos^2 \beta \epsilon_Y \end{aligned} \quad (77)$$

$$\begin{bmatrix} \epsilon_X & \gamma_{XY}/2 \\ \gamma_{XY}/2 & \epsilon_Y \end{bmatrix} = \mathbf{R}^T \begin{bmatrix} \epsilon_x & \gamma_{xy}/2 \\ \gamma_{xy}/2 & \epsilon_y \end{bmatrix} \mathbf{R} \quad (78)$$

$$\begin{aligned} \epsilon_X &= \cos^2 \beta \epsilon_x - \sin \beta \cos \beta \gamma_{xy} + \sin^2 \beta \epsilon_y \\ \gamma_{XY} &= 2 \sin \beta \cos \beta \epsilon_x + (\cos^2 \beta - \sin^2 \beta) \gamma_{xy} - 2 \sin \beta \cos \beta \epsilon_y \\ \epsilon_Y &= \sin^2 \beta \epsilon_x + \sin \beta \cos \beta \gamma_{xy} + \cos^2 \beta \epsilon_y \end{aligned} \quad (79)$$

Local reference frames

The COQI triangular plate element [12, 13] uses a local reference frame as shown in Figure 6 (a). The element's stresses and strains (at Gauss points) are expressed in this reference frame, which is the same for all Gauss points of each element, but varies of course from element to element. The reference frame axes x and y lie in the plane of the element. The x axis bisecates the angle at the first vertex of the element. The z axis is normal to the element plane and directed along the “positive” normal to the element according to right-hand rule. The y axis is normal to the first two according to the right-hand rule.

The CQD3 triangular shell element [10, 11] uses a local “lamina” reference frame which in general varies from Gauss point to Gauss point in the lamina, but is the same for all Gauss points along

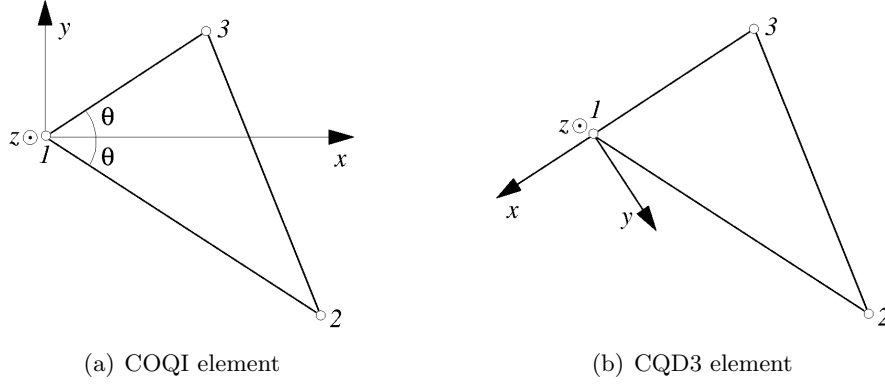


Figure 6: Local reference frames.

the fiber (i.e., through the element thickness) at any given lamina position. Stresses and strains are expressed in the lamina system.

The construction of the lamina basis is detailed in Section 2.1.4 of reference [10]. However, upon inspection, it was found out that the algorithm actually implemented in the code is slightly different from the one in the report.

The implemented algorithm is as follows. Let L_1 , L_2 , L_3 be the local (or parent) coordinates of the triangular element, as shown in Figure 7 (a) for the linear element CQD3 and in Figure 7 (b) for the parabolic element CQD6. These are also called the area coordinates of the triangle. Only two of the area coordinates are independent, since $L_1 + L_2 + L_3 = 1$.

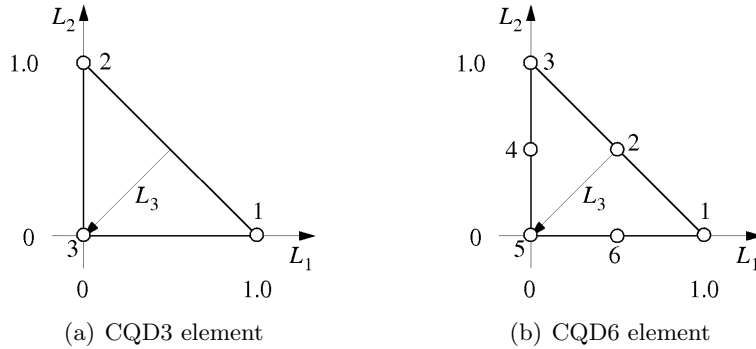


Figure 7: Parent elements for the CQDx triangular shells.

The local x axis is taken along the L_1 direction, i.e. along the line that joins node 3 to node 1 of the CQD3 triangle, in local numbering. The local z axis is normal to the triangle (according to the right-hand rule) and the local y axis is normal to the other two, see Figure 6 (b). This construction is different (in the element plane) from the one reported in reference [10], where the local x, y reference would be “averaged” around the local axes L_1, L_2 (so that x would *not* coincide with L_1 in general, unless the triangle has a right angle at vertex 3).

By following reference [10], we see that at each Gauss point a lamina (orthogonal) matrix \mathbf{q} is built up:

$$\mathbf{q} = [q_{ij}] = [\hat{\ell}_1 \quad \hat{\ell}_2 \quad \hat{\ell}_3]^T \quad : \quad \text{global} \longrightarrow \text{lamina} \quad (80)$$

where the $\hat{\ell}_I$ are the unit lamina frame vectors which coincide with the x, y, z directions built as explained above. A vector \mathbf{v} is transformed from the global basis to the lamina basis according to:

$$\mathbf{v}_{\text{lamina}} = \mathbf{q} \mathbf{v}_{\text{global}} \quad (81)$$

By comparing equations (67) and (81) one sees that the lamina matrix \mathbf{q} coincides with the rotation matrix \mathbf{R} that has been considered above:

$$\mathbf{q} = \mathbf{R} \quad (82)$$

Therefore, in order to compute the stresses or strains in the global frame starting from those in the lamina frame, one can use two alternative (equivalent) methods:

- Compute the lamina basis, i.e. the \mathbf{q} matrix, which coincides with \mathbf{R} as noted, and then apply equation (73) or (78), or
- Compute the angle β and then apply equation (74) or (79) directly.

In order to use the first method above, one can either compute the \mathbf{q} matrix by hand according to the definition (80), which is probably a bit laborious, or extract the values directly from the code. In the EPX code the \mathbf{q} matrix values are stored in the array `VARELM` for the CQDx family of elements.

The second method is simpler in the present case (2D), since the angle β can be evaluated directly by looking at the mesh and by considering the local element numbering: it is the angle which brings the global X axis onto the local x axis by rotating in the anti-clockwise direction.

With the conventions explained above, the local reference frames for the COQI elements used in test case COQIS3 and those for the CQD3 elements used in case CQD3S3 are as shown in Figure 8 (a) and (b), respectively. The X and Y axes are the global axes, while x_I , y_I are the local axes for element I . Note that, as already mentioned, the COQI has a single local reference for all Gauss points, while for CQD3 if one uses the reduced integration rule, which is the default and the one used in case CQD3S3, there is just one Gauss point in the lamina, so that there is just one lamina reference per element. The thin arrows indicate the numbering of the elements: for example, element 1 is numbered 1, 2, 3.

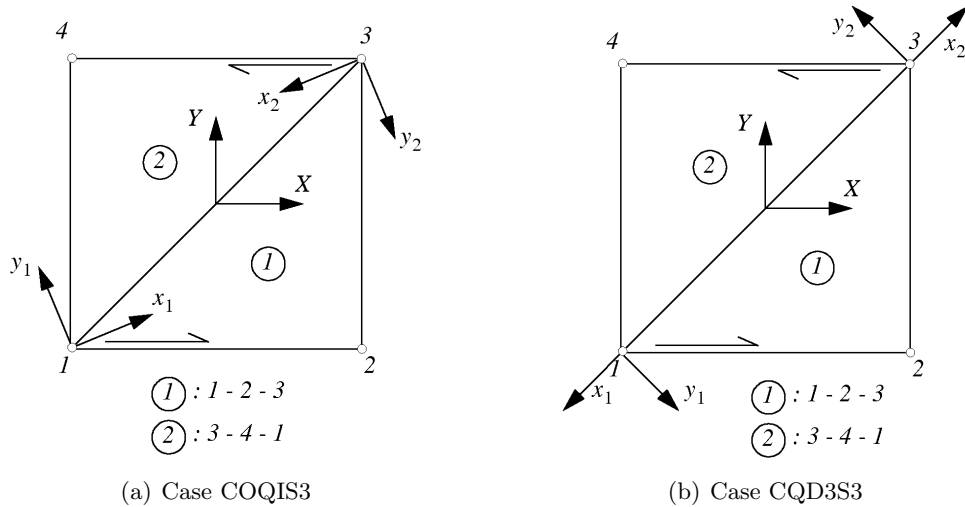


Figure 8: Local reference frames in test cases COQIS3 and CQD3S3.

It is readily seen that the β angles for the elements 1 and 2 are $\beta_1 = 22.5^\circ$, $\beta_2 = 202.5^\circ$ in the COQIS3 case (Figure 8 (a)), and $\beta_1 = 225^\circ$, $\beta_2 = 45^\circ$ in the CQD3S3 case (Figure 8 (b)).

The lamina reference frames shown in Figure 8 are those in the initial configuration of the tests. However, in order to compute the global stresses or strains at the end of the test (for comparison with the analytical solution), one must consider the lamina references in the deformed (final) configuration, as detailed below.

Analysis of COQI results

For the COQI, according to reference [12], the coordinates of the three nodes of an element in the xyz reference frame are supposed to be constant. In other words, the element is formulated in such a way that large displacements and large rotations of the element as a whole (rigid body) are taken into account (by means of a co-rotational approach), but *large strains*, and in particular large membrane

strains, *are not taken into account*. This limitation has been now made much clearer in the EPX Users' manual.

This point had been initially overlooked, since the element even takes into account the thickness variation due to membrane strains. However, the fact that strains must be small (of the order of a few percent at most) explains why the behaviour of the element is so weird in the present test, where engineering strains of 300 % occur in the membrane at the end of the test.

Therefore, it is useless to go on with the analysis of the COQI solution for this test (case COQIS3). Of course, this does not mean that COQI cannot be used with VPJC, but simply that the element must be used within the (membrane) strain range for which it is designed. A different (small-strain) test case should be set up for COQI to check the VPJC implementation for this element.

Analysis of CQD3 results

For the CQD3 the final shape of element 1 in test case CQD3S3 is shown in Figure 9 (b). At this moment the “height” L_y of the element is 3 units, as imposed in the test. The element “width” L_x can be computed from the analytical solution. According to Table 3 the “horizontal” strain should be $\epsilon_x = -0.54931$. Since this is a natural (logarithmic) strain, we get:

$$L_x = L_{x0} \exp(\epsilon_x) = 1.0 \exp(-0.54931) = 0.577 \quad (83)$$

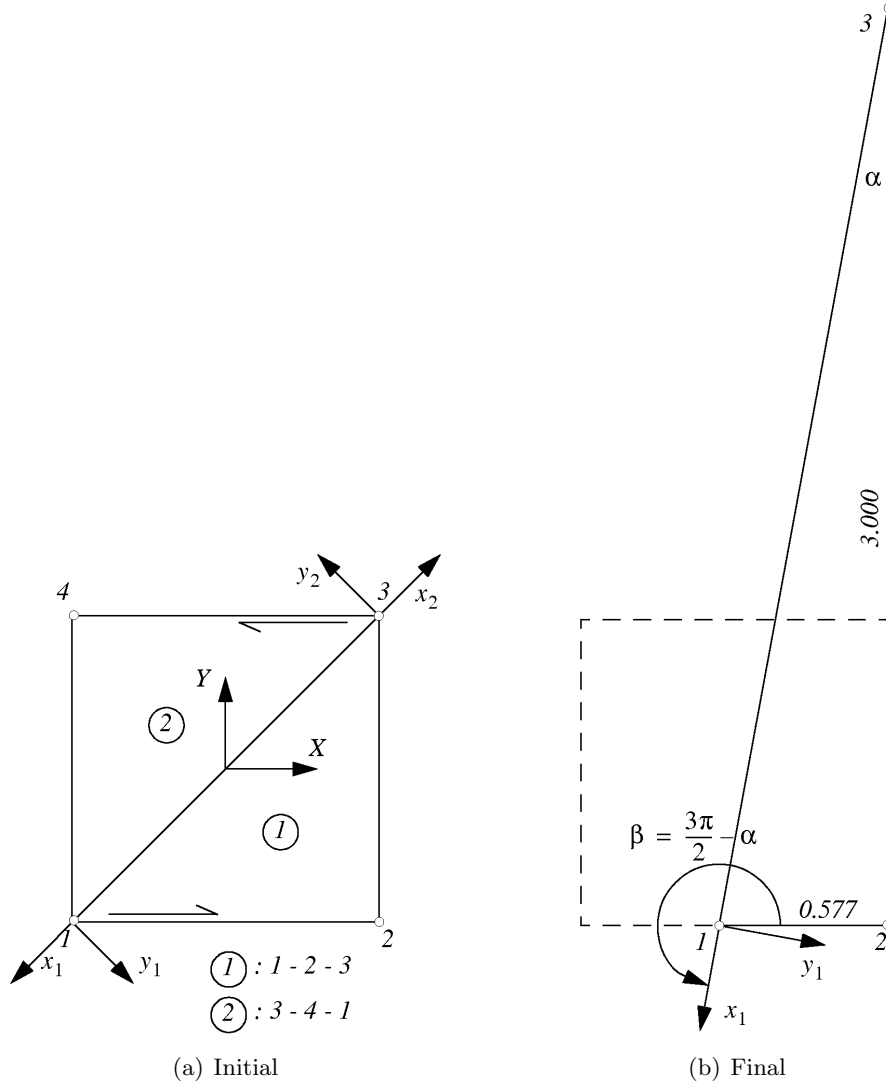


Figure 9: Element deformation in test CQD3S3.

This value of the width is exactly confirmed by reading out the results in the code listing. The angle α at the element's top (see Figure 9 (b)) is:

$$\alpha = \arctan\left(\frac{L_x}{L_y}\right) = \arctan\left(\frac{0.577}{3.000}\right) = 10.9^\circ \quad (84)$$

so that the angle β is:

$$\beta = 270.0 - \alpha = 259.1^\circ \quad (85)$$

and:

$$\begin{aligned} \sin \beta &= -0.982 \\ \cos \beta &= -0.189 \\ \sin^2 \beta &= 0.964 \\ \cos^2 \beta &= 0.036 \\ \sin \beta \cos \beta &= 0.186 \\ 2 \sin \beta \cos \beta &= 0.371 \end{aligned} \quad (86)$$

By dumping out from the code the contents of the \mathbf{q} matrix at the final time step we find, for element 1:

$$\mathbf{q}_1 = \begin{bmatrix} -0.189 & -0.982 & 0.000 \\ 0.982 & -0.189 & 0.000 \\ 0.000 & 0.000 & 1.000 \end{bmatrix} = \mathbf{R}_1 = \begin{bmatrix} \cos \beta & \sin \beta & 0 \\ -\sin \beta & \cos \beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (87)$$

which is in excellent agreement with the expression (68) of \mathbf{R} . For element 2, incidentally, we have $\beta_2 = 90 - 10.9 = 79.1^\circ$, $\sin \beta_2 = 0.982$, $\cos \beta_2 = 0.189$ and, from the code:

$$\mathbf{q}_2 = \begin{bmatrix} 0.189 & 0.982 & 0.000 \\ -0.982 & 0.189 & 0.000 \\ 0.000 & 0.000 & 1.000 \end{bmatrix} = \mathbf{R}_2 = \begin{bmatrix} \cos \beta_2 & \sin \beta_2 & 0 \\ -\sin \beta_2 & \cos \beta_2 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (88)$$

which is also correct. From the code listing at the final time we find the following results in terms of stress and strain components expressed in the local (lamina) basis for element 1 (see also Table 3):

$$\begin{aligned} \sigma_x &= 9.7537 \times 10^8 & \sigma_y &= 0.3618 \times 10^8 & \tau_{xy} &= 1.8781 \times 10^8 & \sigma_z &= 0.0 \\ \epsilon_x &= 1.3540 & \epsilon_y &= -0.80421 & \gamma_{xy} &= 0.77012 & \epsilon_z &= -0.54820 \end{aligned} \quad (89)$$

From equation (74) we obtain the stresses expressed in the global system:

$$\begin{aligned} \sigma_X &= \cos^2 \beta \sigma_x - 2 \sin \beta \cos \beta \tau_{xy} + \sin^2 \beta \sigma_y \\ &= 0.036 \cdot 9.7537 \times 10^8 - 0.371 \cdot 1.8781 \times 10^8 + 0.964 \cdot 0.3618 \times 10^8 \\ &= 0.003 \times 10^8 \end{aligned} \quad (90)$$

$$\begin{aligned} \tau_{XY} &= \sin \beta \cos \beta \sigma_x + (\cos^2 \beta - \sin^2 \beta) \tau_{xy} - \sin \beta \cos \beta \sigma_y \\ &= 0.186 \cdot 9.7537 \times 10^8 + (0.036 - 0.964) \cdot 1.8781 \times 10^8 - 0.186 \cdot 0.3618 \times 10^8 \\ &= 0.004 \times 10^8 \end{aligned} \quad (91)$$

$$\begin{aligned} \sigma_Y &= \sin^2 \beta \sigma_x + 2 \sin \beta \cos \beta \tau_{xy} + \cos^2 \beta \sigma_y \\ &= 0.964 \cdot 9.7537 \times 10^8 + 0.371 \cdot 1.8781 \times 10^8 + 0.036 \cdot 0.3618 \times 10^8 \\ &= 10.112 \times 10^8 \end{aligned} \quad (92)$$

These results are in very good agreement with the analytical solution: $\sigma_X = 0$, $\tau_{XY} = 0$ and $\sigma_Y = 10.116 \times 10^8$ (see also Table 3).

From equation (79) we obtain the strains expressed in the global system:

$$\begin{aligned}\epsilon_X &= \cos^2 \beta \epsilon_x - \sin \beta \cos \beta \gamma_{xy} + \sin^2 \beta \epsilon_y \\ &= 0.036 \cdot 1.3540 - 0.186 \cdot 0.77012 + 0.964 \cdot (-0.80421) \\ &= -0.869\end{aligned}\tag{93}$$

$$\begin{aligned}\gamma_{XY} &= 2 \sin \beta \cos \beta \epsilon_x + (\cos^2 \beta - \sin^2 \beta) \gamma_{xy} - 2 \sin \beta \cos \beta \epsilon_y \\ &= 0.371 \cdot 1.3540 + (0.036 - 0.964) \cdot 0.77012 - 0.371 \cdot (-0.80421) \\ &= 0.086\end{aligned}\tag{94}$$

$$\begin{aligned}\epsilon_Y &= \sin^2 \beta \epsilon_x + \sin \beta \cos \beta \gamma_{xy} + \cos^2 \beta \epsilon_y \\ &= 0.964 \cdot 1.3540 + 0.186 \cdot 0.77012 + 0.036 \cdot (-0.80421) \\ &= 1.420\end{aligned}\tag{95}$$

The results for the strains are very different from the analytical solution: $\epsilon_X = -0.54931$, $\gamma_{XY} = 0$ and $\epsilon_Y = 1.0986$ (see also Table 3). These results have been checked independently by using the expression (73) involving the rotation matrix \mathbf{R} instead of equation (79) (see small Fortran programs `chkeps3.f` or `chkeps2.f` and the corresponding outputs `chkeps3.txt` or `chkeps2.txt` in Appendix B) and are confirmed.

This indicates that the total strains are wrongly computed by the code in example CQD3S3. Still, the calculation is correct in the sense that the stresses and the resultant forces are in excellent agreement with the reference solution (which of course is the most important thing).

While it would be nice to understand why the total strains are incorrectly estimated, it is recalled that the total strain tensor is just a post-processing quantity in the EPX code. In other words, total strains are computed and printed out for the user's convenience, but do not intervene in any way in the actual calculations, due to the incremental nature of the constitutive law implementations (perhaps with the exception of some failure criteria which may sometimes be based upon total strain).

A final general observation may be raised on the presentation of results from the EPX code. The calculations presented in this Section are very laborious and error-prone. They are needed just to express the stress or strain in a different reference frame (the global frame in this case) from the standard one in which results are normally presented (the element- or Gauss-point based frame, for shell elements).

One might argue that such operations would be best done by the code itself rather than by cumbersome hand calculations. Indeed, the code contains all the information (transformation matrices etc.) needed to transform the results in any reference system that would be convenient for the user. So, one might think of adding an option or a similar feature that would instruct the code to produce the results (also) in a different reference frame from the standard one.

However, it is also true that for shells and similar elements, expressing the stresses or strains in the global reference frame would very rarely make sense. It is only useful in the present case, due to the specific set-up of the numerical test (for ease of comparison with an analytical solution).

To summarize the conclusions of this Section: *i*) the COQI element is inadequate for tests involving large membrane strains and *ii*) the CQD3 triangular shell element (and also the parabolic element CQD6 which behaves similarly) gives wrong total strain results, although the main engineering results (stresses and forces) are correct.

Appendix B — Input files

All the input files used in the previous Sections are listed below.

c272g2.epx

```
C272G2
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 27 C272 1 TERM
-0.5 -0.5 -0.5      0.5 -0.5 -0.5      0.5 0.5 -0.5      -0.5 0.5 -0.5
-0.5 -0.5 0.5      0.5 -0.5 0.5      0.5 0.5 0.5      -0.5 0.5 0.5
0 0 -0.5      0 -0.5 0      0.5 0 0      0 0.5 0
-0.5 0 0      0 0 0.5      0 -0.5 -0.5      0.5 0 -0.5
0 0.5 -0.5      -0.5 0 -0.5      -0.5 -0.5 0      0.5 -0.5 0
0.5 0.5 0      -0.5 0.5 0      0 -0.5 0.5      0.5 0 0.5
0 0.5 0.5      -0.5 0 0.5      0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27
MATE VJPC RO 7850.0 ! Docol 600 steel parameters
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 9 15 16 17 18 TERM ! Relative velocity
VITE 3 0.5 FONC 1 LECT 5 6 7 8 14 23 24 25 26 TERM ! 1 m/s
RELA 4 EGAL 1 LECT 1 4 5 8 13 18 19 22 26 TERM
EGAL 1 LECT 2 3 6 7 11 16 20 21 24 TERM
EGAL 2 LECT 1 2 5 6 10 15 19 20 23 TERM
EGAL 2 LECT 3 4 7 8 12 17 21 22 25 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRQ FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRQ COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRQ COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 14 23 24 25 26 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
CONT COMP 4 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-ZZ
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FZ-SUM
FIN
```

c272g2a.epx

```
C272G2A
ECHO
CONV WIN
```

```
OPTI PRIN
RESU ALIC 'c272g2.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 -8.29161E+00 -1.70063E-09
! Q 7.07107E-01 7.07107E-01 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 1.00000E+00 2.05102E-10
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 -2.05102E-10 1.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.65832E+00
!RADIUS : 8.29161E+00
!ASPECT : 1.00000E+00
!NEAR : 6.46746E+00
!FAR : 1.16083E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KPFE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN
```

c272g2p.epx

```
C272G2P
ECHO
OPTI PRIN
RESU ALIC 'c272g2.ali' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR 11 'dx_1' DEPL COMP 1 NOEU LECT 1 TERM
COUR 12 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR 21 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 22 'fz_8' FLIA COMP 3 NOEU LECT 8 TERM
COUR 31 's1_gp1' CONT COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 32 's2_gp1' CONT COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 33 's3_gp1' CONT COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 34 's4_gp1' CONT COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 35 's5_gp1' CONT COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 36 's6_gp1' CONT COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 41 'SIGMAH' ECRQ COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 42 'PHI' ECRQ COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 43 'P' ECRQ COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 44 'PHITRIAL' ECRQ COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 45 'F' ECRQ COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 46 'R' ECRQ COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 47 'DDLAMBDA' ECRQ COMP 7 GAUS 1 ELEM LECT 1 TERM
COUR 48 'DLAMBDA' ECRQ COMP 8 GAUS 1 ELEM LECT 1 TERM
COUR 49 'NRITER' ECRQ COMP 9 GAUS 1 ELEM LECT 1 TERM
COUR 50 'DLAMBDA/DT' ECRQ COMP 10 GAUS 1 ELEM LECT 1 TERM
COUR 51 'D' ECRQ COMP 11 GAUS 1 ELEM LECT 1 TERM
COUR 52 'FAILURE' ECRQ COMP 12 GAUS 1 ELEM LECT 1 TERM
COUR 53 'T' ECRQ COMP 13 GAUS 1 ELEM LECT 1 TERM
COUR 54 'WE' ECRQ COMP 14 GAUS 1 ELEM LECT 1 TERM
COUR 61 'e1_gp1' EPST COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 62 'e2_gp1' EPST COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 63 'e3_gp1' EPST COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 64 'e4_gp1' EPST COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 65 'e5_gp1' EPST COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 66 'e6_gp1' EPST COMP 6 GAUS 1 ELEM LECT 1 TERM
TRAC 1 2 11 12 AXES 1.0 'DISPL. [M]' YZER
TRAC 21 22 AXES 1.0 'FZLIA [N]' YZER
TRAC 31 32 33 34 35 36 AXES 1.0 'STRESS [PA]' YZER
TRAC 61 62 63 64 65 66 AXES 1.0 'STRAIN [-]' YZER
TRAC 41 AXES 1.0 'SIGMAH' YZER
TRAC 42 AXES 1.0 'PHI' YZER
TRAC 43 AXES 1.0 'P' YZER
TRAC 44 AXES 1.0 'PHITRIAL' YZER
TRAC 45 AXES 1.0 'F' YZER
TRAC 46 AXES 1.0 'R' YZER
TRAC 47 AXES 1.0 'DDLAMBDA' YZER
TRAC 48 AXES 1.0 'DLAMBDA' YZER
TRAC 49 AXES 1.0 'NRITER' YZER
TRAC 50 AXES 1.0 'DLAMBDA/DT' YZER
TRAC 51 AXES 1.0 'D' YZER
TRAC 52 AXES 1.0 'FAILURE' YZER
TRAC 53 AXES 1.0 'T' YZER
TRAC 54 AXES 1.0 'WE' YZER
COUR 101 'x_1' COOR COMP 1 NOEU LECT 1 TERM
COUR 102 'x_2' COOR COMP 1 NOEU LECT 2 TERM
COUR 201 'y_1' COOR COMP 2 NOEU LECT 1 TERM
COUR 204 'y_4' COOR COMP 2 NOEU LECT 4 TERM
```

```

COUR 301 'z_1' COOR COMP 3 NOEU LECT 1 TERM
COUR 305 'z_5' COOR COMP 3 NOEU LECT 5 TERM
TRAC 101 102 201 204 301 305 AXES 1.0 'COORD' YZER
COUR 401 'dx' SUB 102 101
COUR 402 'dy' SUB 204 201
COUR 403 'dz' SUB 305 301
TRAC 401 402 403 AXES 1.0 'LENGTHS' YZER
COUR 404 'dxdy' MUL 401 402
TRAC 404 AXES 1.0 'AREA' YZER
COUR 405 'vol' MUL 404 403
TRAC 405 AXES 1.0 'VOLUME' YZER
RCOU 501 'ez' FICH 'ez.pun' RENA 'ez_ana'
TRAC 64 501 AXES 1.0 'STRAIN [-]' YZER
COLO NOIR ROUG
FIN

```

c273g2.epx

```

C273G2
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 27 C273 1 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 0.5 -0.5 0.5 0.5
0 0 -0.5 0 -0.5 0 0.5 0 0 0 0.5 0
-0.5 0 0 0 0 0.5 0 -0.5 -0.5 0.5 0 -0.5
0 0.5 -0.5 -0.5 0 -0.5 -0.5 -0.5 0 0.5 -0.5 0
0.5 0.5 0 -0.5 0.5 0 0 -0.5 0.5 0.5 0 0.5
0 0.5 0.5 -0.5 0 0.5 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27
MATE VPJC RD 7850.0 ! Docol 600 steel parameters
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDDT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 9 15 16 17 18 TERM ! Relative velocity
VITE 3 0.5 FONC 1 LECT 5 6 7 8 14 23 24 25 26 TERM ! 1 m/s
RELA 4 EGAL 1 LECT 1 4 5 8 13 18 19 22 26 TERM
EGAL 1 LECT 2 3 6 7 11 16 20 21 24 TERM
EGAL 2 LECT 1 2 5 6 10 15 19 20 23 TERM
EGAL 2 LECT 3 4 7 8 12 17 21 22 25 TERM
ECRI COOR DEPL VITE ACCE FINI TEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 14 23 24 25 26 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [m]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ

```

```

CONT COMP 4 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-ZZ
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FZ-SUM
FIN

c273g2a.epx

C273G2A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'c273g2.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 -8.29161E+00 -1.70063E-09
! Q 7.07107E-01 7.07107E-01 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 1.00000E+00 2.05102E-10
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 -2.05102E-10 1.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.65832E+00
!RADIUS : 8.29161E+00
!ASPECT : 1.00000E+00
!NEAR : 6.46746E+00
!FAR : 1.16083E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

c273g2p.epx

C273G2P
ECHO
OPTI PRIN
RESU ALIC 'c273g2.ali' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR 11 'dx_1' DEPL COMP 1 NOEU LECT 1 TERM
COUR 12 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR 21 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 22 'fz_8' FLIA COMP 3 NOEU LECT 8 TERM
COUR 31 's1_gp1' CONT COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 32 's2_gp1' CONT COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 33 's3_gp1' CONT COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 34 's4_gp1' CONT COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 35 's5_gp1' CONT COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 36 's6_gp1' CONT COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 41 'SIGMAH' ECRO COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 42 'PHI' ECRO COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 43 'P' ECRO COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 44 'PHITRIAL' ECRO COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 45 'F' ECRO COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 46 'R' ECRO COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 47 'DDLAMBDA' ECRO COMP 7 GAUS 1 ELEM LECT 1 TERM
COUR 48 'DLAMBDA' ECRO COMP 8 GAUS 1 ELEM LECT 1 TERM
COUR 49 'NRITER' ECRO COMP 9 GAUS 1 ELEM LECT 1 TERM
COUR 50 'DLAMBDA/DT' ECRO COMP 10 GAUS 1 ELEM LECT 1 TERM
COUR 51 'D' ECRO COMP 11 GAUS 1 ELEM LECT 1 TERM
COUR 52 'FAILURE' ECRO COMP 12 GAUS 1 ELEM LECT 1 TERM
COUR 53 'T' ECRO COMP 13 GAUS 1 ELEM LECT 1 TERM
COUR 54 'WE' ECRO COMP 14 GAUS 1 ELEM LECT 1 TERM
COUR 61 'e1_gp1' EPST COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 62 'e2_gp1' EPST COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 63 'e3_gp1' EPST COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 64 'e4_gp1' EPST COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 65 'e5_gp1' EPST COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 66 'e6_gp1' EPST COMP 6 GAUS 1 ELEM LECT 1 TERM
TRAC 1 2 11 12 AXES 1.0 'DISPL. [m]' YZER
TRAC 21 22 AXES 1.0 'FZLIA [N]' YZER
TRAC 31 32 33 34 35 36 AXES 1.0 'STRESS [PA]' YZER
TRAC 61 62 63 64 65 66 AXES 1.0 'STRAIN [-]' YZER
TRAC 41 AXES 1.0 'SIGMAH' YZER
TRAC 42 AXES 1.0 'PHI' YZER
TRAC 43 AXES 1.0 'P' YZER
TRAC 44 AXES 1.0 'PHITRIAL' YZER
TRAC 45 AXES 1.0 'F' YZER
TRAC 46 AXES 1.0 'R' YZER
TRAC 47 AXES 1.0 'DDLAMBDA' YZER
TRAC 48 AXES 1.0 'DLAMBDA' YZER
TRAC 49 AXES 1.0 'NRITER' YZER
TRAC 50 AXES 1.0 'DLAMBDA/DT' YZER
TRAC 51 AXES 1.0 'D' YZER
TRAC 52 AXES 1.0 'FAILURE' YZER
TRAC 53 AXES 1.0 'T' YZER
TRAC 54 AXES 1.0 'WE' YZER
COUR 101 'x_1' COOR COMP 1 NOEU LECT 1 TERM
COUR 102 'x_2' COOR COMP 1 NOEU LECT 2 TERM
COUR 201 'y_1' COOR COMP 2 NOEU LECT 1 TERM

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COUR 204 'y_4' COOR COMP 2 NOEU LECT 4 TERM
COUR 301 'z_1' COOR COMP 3 NOEU LECT 1 TERM
COUR 305 'z_5' COOR COMP 3 NOEU LECT 5 TERM
TRAC 101 102 201 204 301 305 AXES 1.0 'COOR' YZER
COUR 401 'dx' SUB 102 101
COUR 402 'dy' SUB 204 201
COUR 403 'dz' SUB 305 301
TRAC 401 402 403 AXES 1.0 'LENGTHS' YZER
COUR 404 'dxdy' MUL 401 402
TRAC 404 AXES 1.0 'AREA' YZER
COUR 405 'vol' MUL 404 403
TRAC 405 AXES 1.0 'VOLUME' YZER
RCOU 501 'ez' FICH 'ez.pun' RENA 'ez_ana'
TRAC 64 501 AXES 1.0 'STRAIN [-]' YZER
COLO NOIR ROUG
FIN

```

c81l02.epx

```

C81l02
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 8 C81L 1 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 0.5 -0.5 0.5 0.5
1 2 3 4 5 6 7 8
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
INIT VITE 3 -0.5 LECT 1 2 3 4 TERM
VITE 3 0.5 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
CONT COMP 4 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-ZZ
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FZ-SUM
FIN

```

c82l02.epx

```

C82L02
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 8 C82L 1 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 0.5 -0.5 0.5 0.5
1 2 3 4 5 6 7 8
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
INIT VITE 3 -0.5 LECT 1 2 3 4 TERM
VITE 3 0.5 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
CONT COMP 4 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-ZZ
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FZ-SUM
FIN

```

car101.epx

```

CAR101
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 4 CAR1 1 TERM
-0.5 -0.5 0.5 -0.5 0.5 0.5 -0.5 0.5
1 2 3 4
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0

```

```

      WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
      LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
      2.0 1.0
LINK COUP
  VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
  VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
  VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
  FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
  JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSQR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [m]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [Pa]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 12 AXES 1.0 'STRESS [Pa]' XAXE 22 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [Pa]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
  EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
  EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
  CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

```

car401.epx

```

CAR401
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 4 CAR4 1 TERM
-0.5 -0.5 0.5 -0.5 0.5 0.5 -0.5 0.5
1 2 3 4
MATE VJPJC RO 7850.0
  YOUN 2.1E11
  NU 0.33
  ELAS 3.70E8
  QR1 2.364E8
  CR1 39.3
  QR2 4.081E8
  CR2 4.5
  PDDOT 5.E-4
  C 0.0
  TQ 0.9 ! We assume adiabatic conditions
  CP 452.0
  TM 1800.0
  M 0.0 ! Zero M : no temperature-induced softening
  DC 1.0
  WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
      LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
      2.0 1.0
LINK COUP
  VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
  VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
  VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
  FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
  JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSQR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM

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COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [m]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [Pa]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 12 AXES 1.0 'STRESS [Pa]' XAXE 22 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [Pa]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
  EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
  EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
  CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

```

chkeps2.f

```

PROGRAM chkeps2
IMPLICIT NONE
REAL(8) :: el(2,2), eg(2,2), r(2,2), rt(2,2), tmp(2,2)
REAL(8) :: pgr, bet, s, c, s2, c2, sc, sc2
DATA pgr /3.141592654D0/

*
  bet = 259.107E0*pgr/180.D0
  s = SIN(bet)
  c = COS(bet)
  s2 = s*s
  c2 = c*c
  sc = s*c
  sc2 = 2.D0*s*c
  WRITE(6,1) bet, s, c, s2, c2, sc, sc2
1 FORMAT(' bet=',F10.3,/,
> ' s =',F6.3,/,
> ' c =',F6.3,/,
> ' s2 =',F6.3,/,
> ' c2 =',F6.3,/,
> ' sc =',F6.3,/,
> ' sc2=',F6.3)

*
  r(1,1) = c
  r(1,2) = s
  r(2,1) = -s
  r(2,2) = c
  CALL PRMAT2 ('R ',r)

*
  el(1,1) = 1.3540D0
  el(1,2) = 0.77012D0 / 2.D0
  el(2,1) = 0.77012D0 / 2.D0
  el(2,2) = -0.80421D0
  CALL PRMAT2 ('EL ',el)

*
  CALL MATRA2 (r, rt)
  CALL PRMAT2 ('RT ',rt)
  CALL MULMA2 (el, r, tmp)
  CALL PRMAT2 ('TMP',tmp)
  CALL MULMA2 (rt, tmp, eg)
  CALL PRMAT2 ('EG ',eg)

*
  END PROGRAM chkeps2

*-----
SUBROUTINE PRMAT3(LAB,A)
* print a 3x3 matrix
IMPLICIT NONE
CHARACTER*3, INTENT(IN) :: LAB
REAL(8), INTENT(IN) :: A(3,3)
WRITE(6,1) LAB
1 FORMAT (A3,':')
WRITE(6,2) A(1,1), A(1,2), A(1,3)
WRITE(6,2) A(2,1), A(2,2), A(2,3)
WRITE(6,2) A(3,1), A(3,2), A(3,3)
2 FORMAT (1P3E12.5)
END SUBROUTINE PRMAT3

*-----
SUBROUTINE PRMAT2(LAB,A)
* print a 2x2 matrix
IMPLICIT NONE
CHARACTER*3, INTENT(IN) :: LAB
REAL(8), INTENT(IN) :: A(2,2)
WRITE(6,1) LAB
1 FORMAT (A3,':')
WRITE(6,2) A(1,1), A(1,2)
WRITE(6,2) A(2,1), A(2,2)
2 FORMAT (1P2E12.5)
END SUBROUTINE PRMAT2

*-----
SUBROUTINE MULMA3(A,B,C)
* multiplies two 3x3 matrices

```

```

      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(3,3),B(3,3)
      REAL(8), INTENT(OUT) :: C(3,3)
      INTEGER :: I,J,K
* compute c = a . b
      DO 50 I=1,3
      DO 40 J=1,3
      C(I,J)=0.
      DO 30 K=1,3
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
      30 CONTINUE
      40 CONTINUE
      50 CONTINUE
      END SUBROUTINE MULMA3

```

```

-----
      SUBROUTINE MULMA2(A,B,C)
* multiplies two 2x2 matrices
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(2,2),B(2,2)
      REAL(8), INTENT(OUT) :: C(2,2)
      INTEGER :: I,J,K
* compute c = a . b
      DO 50 I=1,2
      DO 40 J=1,2
      C(I,J)=0.
      DO 30 K=1,2
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
      30 CONTINUE
      40 CONTINUE
      50 CONTINUE
      END SUBROUTINE MULMA2
-----
      SUBROUTINE MATRA3(A,B)
* computes transpose of a 3x3 matrix
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(3,3)
      REAL(8), INTENT(OUT) :: B(3,3)
* compute b = a ^ T
      B(1,1) = A(1,1)
      B(1,2) = A(2,1)
      B(1,3) = A(3,1)
      B(2,1) = A(1,2)
      B(2,2) = A(2,2)
      B(2,3) = A(3,2)
      B(3,1) = A(1,3)
      B(3,2) = A(2,3)
      B(3,3) = A(3,3)
      END SUBROUTINE MATRA3

```

```

-----
      SUBROUTINE MATRA2(A,B)
* computes transpose of a 2x2 matrix
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(2,2)
      REAL(8), INTENT(OUT) :: B(2,2)
* compute b = a ^ T
      B(1,1) = A(1,1)
      B(1,2) = A(2,1)
      B(2,1) = A(1,2)
      B(2,2) = A(2,2)
      END SUBROUTINE MATRA2

```

chkeps2.txt

```

bet=      4.522
s      =-0.982
c      =-0.189
s2     = 0.964
c2     = 0.036
sc      = 0.186
sc2=    0.371
R      :
-1.88976E-01-9.81982E-01
 9.81982E-01-1.88976E-01
EL      :
 1.35400E+00 3.85060E-01
 3.85060E-01-8.04210E-01
RT      :
-1.88976E-01 9.81982E-01
-9.81982E-01-1.88976E-01
TMP:
 1.22249E-01-1.40237E+00
-8.62487E-01-2.26146E-01
EG      :
-8.70048E-01 4.29426E-02
 4.29426E-02 1.41984E+00

```

chkeps3.f

```

      PROGRAM chkeps3
      IMPLICIT NONE
      REAL(8) :: el(3,3), eg(3,3), r(3,3), rt(3,3), tmp(3,3)
      REAL(8) :: pgr, bet, s, c, s2, c2, sc, sc2
      DATA pgr /3.141592654D0/
*
      bet = 259.107E0*pgr/180.D0
      s = SIN (bet)
      c = COS (bet)
      s2 = s*s
      c2 = c*c

```

```

      sc = s*c
      sc2 = 2.D0*s*c
      WRITE (6,1) bet, s, c, s2, c2, sc, sc2
1 FORMAT(' bet= ',F10.3,/,
>        ' s   = ',F6.3,/,
>        ' c   = ',F6.3,/,
>        ' s2  = ',F6.3,/,
>        ' c2  = ',F6.3,/,
>        ' sc  = ',F6.3,/,
>        ' sc2 = ',F6.3)

```

```

*
      r(1,1) = c
      r(1,2) = s
      r(1,3) = 0.D0
      r(2,1) = -s
      r(2,2) = c
      r(2,3) = 0.D0
      r(3,1) = 0.D0
      r(3,2) = 0.D0
      r(3,3) = 1.D0
      CALL PRMAT3 ('R ',r)

```

```

*
      el(1,1) = 1.3540D0
      el(1,2) = 0.77012D0 / 2.D0
      el(1,3) = 0.D0
      el(2,1) = 0.77012D0 / 2.D0
      el(2,2) = -0.80421D0
      el(2,3) = 0.D0
      el(3,1) = 0.D0
      el(3,2) = 0.D0
      el(3,3) = -0.54820D0
      CALL PRMAT3 ('EL ',el)

```

```

*
      CALL MATRA3 (r, rt)
      CALL PRMAT3 ('RT ',rt)
      CALL MULMA3 (el, r, tmp)
      CALL PRMAT3 ('TMP',tmp)
      CALL MULMA3 (rt, tmp, eg)
      CALL PRMAT3 ('EG ',eg)

```

```

*
      END PROGRAM chkeps3

```

```

-----
      SUBROUTINE PRMAT3(LAB,A)
* print a 3x3 matrix
      IMPLICIT NONE
      CHARACTER*3, INTENT(IN) :: LAB
      REAL(8), INTENT(IN) :: A(3,3)
      WRITE(6,1) LAB
1 FORMAT (A3,':')
      WRITE(6,2) A(1,1), A(1,2), A(1,3)
      WRITE(6,2) A(2,1), A(2,2), A(2,3)
      WRITE(6,2) A(3,1), A(3,2), A(3,3)
2 FORMAT (1P3E12.5)
      END SUBROUTINE PRMAT3

```

```

-----
      SUBROUTINE PRMAT2(LAB,A)
* print a 2x2 matrix
      IMPLICIT NONE
      CHARACTER*3, INTENT(IN) :: LAB
      REAL(8), INTENT(IN) :: A(2,2)
      WRITE(6,1) LAB
1 FORMAT (A3,':')
      WRITE(6,2) A(1,1), A(1,2)
      WRITE(6,2) A(2,1), A(2,2)
2 FORMAT (1P2E12.5)
      END SUBROUTINE PRMAT2

```

```

-----
      SUBROUTINE MULMA3(A,B,C)
* multiplies two 3x3 matrices
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(3,3),B(3,3)
      REAL(8), INTENT(OUT) :: C(3,3)
      INTEGER :: I,J,K
* compute c = a . b
      DO 50 I=1,3
      DO 40 J=1,3
      C(I,J)=0.
      DO 30 K=1,3
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
      30 CONTINUE
      40 CONTINUE
      50 CONTINUE
      END SUBROUTINE MULMA3

```

```

-----
      SUBROUTINE MULMA2(A,B,C)
* multiplies two 2x2 matrices
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(2,2),B(2,2)
      REAL(8), INTENT(OUT) :: C(2,2)
      INTEGER :: I,J,K

```

```

* compute c = a . b
      DO 50 I=1,2
      DO 40 J=1,2
      C(I,J)=0.
      DO 30 K=1,2
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
      30 CONTINUE
      40 CONTINUE
      50 CONTINUE
      END SUBROUTINE MULMA2

```

```

-----
      SUBROUTINE MATRA3(A,B)
* computes transpose of a 3x3 matrix

```

```

      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(3,3)
      REAL(8), INTENT(OUT) :: B(3,3)
* compute b = a ^ T
      B(1,1) = A(1,1)
      B(1,2) = A(2,1)
      B(1,3) = A(3,1)
      B(2,1) = A(1,2)
      B(2,2) = A(2,2)
      B(2,3) = A(3,2)
      B(3,1) = A(1,3)
      B(3,2) = A(2,3)
      B(3,3) = A(3,3)
      END SUBROUTINE MATRA3
*-----
      SUBROUTINE MATRA2(A,B)
* computes transpose of a 2x2 matrix
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(2,2)
      REAL(8), INTENT(OUT) :: B(2,2)
* compute b = a ^ T
      B(1,1) = A(1,1)
      B(1,2) = A(2,1)
      B(2,1) = A(1,2)
      B(2,2) = A(2,2)
      END SUBROUTINE MATRA2

```

chkeps3.txt

```

bet=      4.522
s  =-0.982
c  =-0.189
s2 = 0.964
c2 = 0.036
sc = 0.186
sc2= 0.371
R   :
-1.88976E-01-9.81982E-01 0.00000E+00
 9.81982E-01-1.88976E-01 0.00000E+00
 0.00000E+00 0.00000E+00 1.00000E+00
EL   :
 1.35400E+00 3.85060E-01 0.00000E+00
 3.85060E-01-8.04210E-01 0.00000E+00
 0.00000E+00 0.00000E+00-5.48200E-01
RT   :
-1.88976E-01 9.81982E-01 0.00000E+00
-9.81982E-01-1.88976E-01 0.00000E+00
 0.00000E+00 0.00000E+00 1.00000E+00
TMP:
 1.22249E-01-1.40237E+00 0.00000E+00
-8.62487E-01-2.26146E-01 0.00000E+00
 0.00000E+00 0.00000E+00-5.48200E-01
EG   :
-8.70048E-01 4.29426E-02 0.00000E+00
 4.29426E-02 1.41984E+00 0.00000E+00
 0.00000E+00 0.00000E+00-5.48200E-01

```

chksig2.f

```

      PROGRAM chksig2
      IMPLICIT NONE
      REAL(8) :: sl(2,2), sg(2,2), r(2,2), rt(2,2), tmp(2,2)
      REAL(8) :: pgr, bet, s, c, s2, c2, sc, sc2
      DATA pgr /3.141592654D0/
*
      bet = 259.107E0*pgr/180.D0
      s = SIN (bet)
      c = COS (bet)
      s2 = s*s
      c2 = c*c
      sc = s*c
      sc2 = 2.D0*s*c
      WRITE (6,1) bet, s, c, s2, c2, sc, sc2
1  FORMAT(' bet=',F10.3,/,
>         ' s  =',F6.3,/,
>         ' c  =',F6.3,/,
>         ' s2 =',F6.3,/,
>         ' c2 =',F6.3,/,
>         ' sc =',F6.3,/,
>         ' sc2=',F6.3)
*
      r(1,1) = c
      r(1,2) = s
      r(2,1) = -s
      r(2,2) = c
      CALL PRMAT2 ('R ',r)
*
      sl(1,1) = 9.7537D8
      sl(1,2) = 1.8781D8
      sl(2,1) = 1.8781D8
      sl(2,2) = 0.3618D8
      CALL PRMAT2 ('SL ',sl)
*
      CALL MATRA2 (r, rt)
      CALL PRMAT2 ('RT ',rt)
      CALL MULMA2 (sl, r, tmp)
      CALL PRMAT2 ('TMP',tmp)
      CALL MULMA2 (rt, tmp, sg)
      CALL PRMAT2 ('SG ',sg)

```

```

*
      END PROGRAM chksig2
*-----
      SUBROUTINE PRMAT3(LAB,A)
* print a 3x3 matrix
      IMPLICIT NONE
      CHARACTER*3, INTENT(IN) :: LAB
      REAL(8), INTENT(IN) :: A(3,3)
      WRITE(6,1) LAB
1  FORMAT (A3,':')
      WRITE(6,2) A(1,1), A(1,2), A(1,3)
      WRITE(6,2) A(2,1), A(2,2), A(2,3)
      WRITE(6,2) A(3,1), A(3,2), A(3,3)
2  FORMAT (1P3E12.5)
      END SUBROUTINE PRMAT3
*-----
      SUBROUTINE PRMAT2(LAB,A)
* print a 2x2 matrix
      IMPLICIT NONE
      CHARACTER*3, INTENT(IN) :: LAB
      REAL(8), INTENT(IN) :: A(2,2)
      WRITE(6,1) LAB
1  FORMAT (A3,':')
      WRITE(6,2) A(1,1), A(1,2)
      WRITE(6,2) A(2,1), A(2,2)
2  FORMAT (1P2E12.5)
      END SUBROUTINE PRMAT2
*-----
      SUBROUTINE MULMA3(A,B,C)
* multiplies two 3x3 matrices
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(3,3),B(3,3)
      REAL(8), INTENT(OUT) :: C(3,3)
      INTEGER :: I,J,K
* compute c = a . b
      DO 50 I=1,3
      DO 40 J=1,3
      C(I,J)=0.
      DO 30 K=1,3
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
30  CONTINUE
40  CONTINUE
50  CONTINUE
      END SUBROUTINE MULMA3
*-----
      SUBROUTINE MULMA2(A,B,C)
* multiplies two 2x2 matrices
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(2,2),B(2,2)
      REAL(8), INTENT(OUT) :: C(2,2)
      INTEGER :: I,J,K
* compute c = a . b
      DO 50 I=1,2
      DO 40 J=1,2
      C(I,J)=0.
      DO 30 K=1,2
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
30  CONTINUE
40  CONTINUE
50  CONTINUE
      END SUBROUTINE MULMA2
*-----
      SUBROUTINE MATRA3(A,B)
* computes transpose of a 3x3 matrix
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(3,3)
      REAL(8), INTENT(OUT) :: B(3,3)
* compute b = a ^ T
      B(1,1) = A(1,1)
      B(1,2) = A(2,1)
      B(1,3) = A(3,1)
      B(2,1) = A(1,2)
      B(2,2) = A(2,2)
      B(2,3) = A(3,2)
      B(3,1) = A(1,3)
      B(3,2) = A(2,3)
      B(3,3) = A(3,3)
      END SUBROUTINE MATRA3
*-----
      SUBROUTINE MATRA2(A,B)
* computes transpose of a 2x2 matrix
      IMPLICIT NONE
      REAL(8), INTENT(IN) :: A(2,2)
      REAL(8), INTENT(OUT) :: B(2,2)
* compute b = a ^ T
      B(1,1) = A(1,1)
      B(1,2) = A(2,1)
      B(2,1) = A(1,2)
      B(2,2) = A(2,2)
      END SUBROUTINE MATRA2

```

chksig2.txt

```

bet=      4.522
s  =-0.982
c  =-0.189
s2 = 0.964
c2 = 0.036
sc = 0.186
sc2= 0.371
R   :

```



```

-1.88976E-01-9.81982E-01
9.81982E-01-1.88976E-01
SL :
9.75370E+08 1.87810E+08
1.87810E+08 3.61800E+07
RT :
-1.88976E-01 9.81982E-01
-9.81982E-01-1.88976E-01
TMP:
1.04904E+05-9.93287E+08
3.66005E+04-1.91263E+08
SG :
1.61167E+04-1.09930E+05
-1.09930E+05 1.01153E+09

```

chksig3.f

```

PROGRAM chksig3
IMPLICIT NONE
REAL(8) :: sl(3,3), sg(3,3), r(3,3), rt(3,3), tmp(3,3)
REAL(8) :: pgr, bet, s, c, s2, c2, sc, sc2
DATA pgr /3.141592654D0/

*
bet = 259.107E0*pgr/180.D0
s = SIN (bet)
c = COS (bet)
s2 = s*s
c2 = c*c
sc = s*c
sc2 = 2.D0*s*c
WRITE (6,1) bet, s, c, s2, c2, sc, sc2
1 FORMAT(' bet=',F10.3,/,
> ' s =',F6.3,/,
> ' c =',F6.3,/,
> ' s2 =',F6.3,/,
> ' c2 =',F6.3,/,
> ' sc =',F6.3,/,
> ' sc2=',F6.3)

*
r(1,1) = c
r(1,2) = s
r(1,3) = 0.D0
r(2,1) = -s
r(2,2) = c
r(2,3) = 0.D0
r(3,1) = 0.D0
r(3,2) = 0.D0
r(3,3) = 1.D0
CALL PRMAT3 ('R ',r)

*
sl(1,1) = 9.7537D8
sl(1,2) = 1.8781D8
sl(1,3) = 0.D0
sl(2,1) = 1.8781D8
sl(2,2) = 0.3618D8
sl(2,3) = 0.D0
sl(3,1) = 0.D0
sl(3,2) = 0.D0
sl(3,3) = 0.D0
CALL PRMAT3 ('SL ',sl)

*
CALL MATRA3 (r, rt)
CALL PRMAT3 ('RT ',rt)
CALL MULMA3 (sl, r, tmp)
CALL PRMAT3 ('TMP',tmp)
CALL MULMA3 (rt, tmp, sg)
CALL PRMAT3 ('SG ',sg)

*
END PROGRAM chksig3

```

```

-----
SUBROUTINE PRMAT3(LAB,A)
* print a 3x3 matrix
IMPLICIT NONE
CHARACTER*3, INTENT(IN) :: LAB
REAL(8), INTENT(IN) :: A(3,3)
WRITE(6,1) LAB
1 FORMAT (A3,':')
WRITE(6,2) A(1,1), A(1,2), A(1,3)
WRITE(6,2) A(2,1), A(2,2), A(2,3)
WRITE(6,2) A(3,1), A(3,2), A(3,3)
2 FORMAT (1P3E12.5)
END SUBROUTINE PRMAT3
-----
SUBROUTINE PRMAT2(LAB,A)
* print a 2x2 matrix
IMPLICIT NONE
CHARACTER*3, INTENT(IN) :: LAB
REAL(8), INTENT(IN) :: A(2,2)
WRITE(6,1) LAB
1 FORMAT (A3,':')
WRITE(6,2) A(1,1), A(1,2)
WRITE(6,2) A(2,1), A(2,2)
2 FORMAT (1P2E12.5)
END SUBROUTINE PRMAT2
-----
SUBROUTINE MULMA3(A,B,C)
* multiplies two 3x3 matrices
IMPLICIT NONE
REAL(8), INTENT(IN) :: A(3,3),B(3,3)
REAL(8), INTENT(OUT) :: C(3,3)
INTEGER :: I,J,K

```

```

* compute c = a . b
DO 50 I=1,3
DO 40 J=1,3
C(I,J)=0.
DO 30 K=1,3
C(I,J)=C(I,J)+A(I,K)*B(K,J)
30 CONTINUE
40 CONTINUE
50 CONTINUE
END SUBROUTINE MULMA3
-----
SUBROUTINE MULMA2(A,B,C)
* multiplies two 2x2 matrices
IMPLICIT NONE
REAL(8), INTENT(IN) :: A(2,2),B(2,2)
REAL(8), INTENT(OUT) :: C(2,2)
INTEGER :: I,J,K
* compute c = a . b
DO 50 I=1,2
DO 40 J=1,2
C(I,J)=0.
DO 30 K=1,2
C(I,J)=C(I,J)+A(I,K)*B(K,J)
30 CONTINUE
40 CONTINUE
50 CONTINUE
END SUBROUTINE MULMA2
-----
SUBROUTINE MATRA3(A,B)
* computes transpose of a 3x3 matrix
IMPLICIT NONE
REAL(8), INTENT(IN) :: A(3,3)
REAL(8), INTENT(OUT) :: B(3,3)
* compute b = a ^ T
B(1,1) = A(1,1)
B(1,2) = A(2,1)
B(1,3) = A(3,1)
B(2,1) = A(1,2)
B(2,2) = A(2,2)
B(2,3) = A(3,2)
B(3,1) = A(1,3)
B(3,2) = A(2,3)
B(3,3) = A(3,3)
END SUBROUTINE MATRA3
-----
SUBROUTINE MATRA2(A,B)
* computes transpose of a 2x2 matrix
IMPLICIT NONE
REAL(8), INTENT(IN) :: A(2,2)
REAL(8), INTENT(OUT) :: B(2,2)
* compute b = a ^ T
B(1,1) = A(1,1)
B(1,2) = A(2,1)
B(2,1) = A(1,2)
B(2,2) = A(2,2)
END SUBROUTINE MATRA2

```

chksig3.txt

```

bet=      4.522
s =-0.982
c =-0.189
s2 = 0.964
c2 = 0.036
sc = 0.186
sc2= 0.371
R :
-1.88976E-01-9.81982E-01 0.00000E+00
9.81982E-01-1.88976E-01 0.00000E+00
0.00000E+00 0.00000E+00 1.00000E+00
SL :
9.75370E+08 1.87810E+08 0.00000E+00
1.87810E+08 3.61800E+07 0.00000E+00
0.00000E+00 0.00000E+00 0.00000E+00
RT :
-1.88976E-01 9.81982E-01 0.00000E+00
-9.81982E-01-1.88976E-01 0.00000E+00
0.00000E+00 0.00000E+00 1.00000E+00
TMP:
1.04904E+05-9.93287E+08 0.00000E+00
3.66005E+04-1.91263E+08 0.00000E+00
0.00000E+00 0.00000E+00 0.00000E+00
SG :
1.61167E+04-1.09930E+05 0.00000E+00
-1.09930E+05 1.01153E+09 0.00000E+00
0.00000E+00 0.00000E+00 0.00000E+00

```

coqis3.epx

```

COQIS3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 COQI 2 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3
3 4 1
COMP EPAI 1.0 LECT 1 2 TERM
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8

```

```

QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDDT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

coqis3a.epx

```

COQIS3A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'coqis3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 1.00000E+00 0.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 37 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 35 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

cqd3s3.epx

```

CQD3S3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 CQD3 2 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3
3 4 1
COMP EPAI 1.0 LECT 1 2 TERM
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDDT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

cqd3s3a.epx

```

CQD3S3A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'cqd3s3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 1.00000E+00 0.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00

```

```

!FAR      : 1.10680E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          INIT WIRE
          VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
          TEXT VSCA
          COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

cqd4s3.epx

```

CQD4S3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 CQD4 1 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
          YOUN 2.1E11
          NU 0.33
          ELAS 3.70E8
          QR1 2.364E8
          CR1 39.3
          QR2 4.081E8
          CR2 4.5
          PDOT 5.E-4
          C 0.0
          TQ 0.9 ! We assume adiabatic conditions
          CP 452.0
          TM 1800.0
          M 0.0 ! Zero M : no temperature-induced softening
          DC 1.0
          WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
          2.0 1.0
LINK COUP
          VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
          VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
          VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
          FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
          EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
          EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
          CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
          COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

cqd4s3a.epx

```

CQD4S3A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'cqd4s3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
  RIGH 1.00000E+00 0.00000E+00 0.00000E+00
  UP 0.00000E+00 1.00000E+00 0.00000E+00
  FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          INIT WIRE
          VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
          TEXT VSCA
          COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

cqd9g3.epx

```

CQD9G3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 9 CQD9 1 TERM
-0.5 -0.5 0.0
0.0 -0.5 0.0
0.5 -0.5 0.0
0.5 0.0 0.0
0.5 0.5 0.0
0.0 0.5 0.0
-0.5 0.5 0.0
-0.5 0.0 0.0
0.0 0.0 0.0
1 2 3 4 5 6 7 8 9
COMP EPAI 1.0 LECT 1 TERM
          INTE FULL LECT 1 TERM
MATE VPJC RO 7850.0
          YOUN 2.1E11
          NU 0.33
          ELAS 3.70E8
          QR1 2.364E8
          CR1 39.3
          QR2 4.081E8
          CR2 4.5
          PDOT 5.E-4
          C 0.0
          TQ 0.9 ! We assume adiabatic conditions
          CP 452.0
          TM 1800.0
          M 0.0 ! Zero M : no temperature-induced softening
          DC 1.0
          WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
          2.0 1.0
LINK COUP
          VITE 2 -0.5 FONC 1 LECT 1 2 3 TERM ! Relative velocity 1 m/s
          VITE 2 0.5 FONC 1 LECT 5 6 7 TERM
          RELA 2 EGAL 1 LECT 1 7 8 TERM
          EGAL 1 LECT 3 4 5 TERM
INIT VITE 2 -0.5 LECT 1 2 3 TERM
          VITE 2 0.5 LECT 5 6 7 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
          FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 3 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 4 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 7 'fy_5' FLIA COMP 2 NOEU LECT 5 TERM
COUR 8 'fy_7' FLIA COMP 2 NOEU LECT 7 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM

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```

COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 5 6 7 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
      EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
      EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
      CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
      COUR 50          REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

cqd9g3a.epx

```

CQD9G3A
ECHO
  CONV WIN
OPTI PRIN
RESU ALIC 'cqd9g3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
!      Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
      VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
      RIGH 1.00000E+00 0.00000E+00 0.00000E+00
      UP 0.00000E+00 1.00000E+00 0.00000E+00
      FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
      REFE FRAM
      INIT WIRE
      VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
      TEXT VSCA
      COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTA 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

cqd9s3.epx

```

CQD9S3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 9 CQD9 1 TERM
-0.5 -0.5 0.0
0.0 -0.5 0.0
0.5 -0.5 0.0
0.5 0.0 0.0
0.5 0.5 0.0
0.0 0.5 0.0
-0.5 0.5 0.0
-0.5 0.0 0.0
0.0 0.0 0.0
1 2 3 4 5 6 7 8 9
COMP EPAI 1.0 LECT 1 TERM
INTE FULL LECT 1 TERM
MATE VPJC RO 7850.0
      YOUN 2.1E11
      NU 0.33
      ELAS 3.70E8
      QR1 2.364E8
      CR1 39.3
      QR2 4.081E8
      CR2 4.5
      PDOT 5.E-4
      C 0.0
      TQ 0.9 ! We assume adiabatic conditions
      CP 452.0
      TM 1800.0
      M 0.0 ! Zero M : no temperature-induced softening
      DC 1.0
      WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
      LECT 1 TERM

```

```

FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
                                2.0 1.0
LINK COUP
      VITE 2 -0.5 FONC 1 LECT 1 2 3 TERM ! Relative velocity 1 m/s
      VITE 2 0.5 FONC 1 LECT 5 6 7 TERM
INIT VITE 2 -0.5 LECT 1 2 3 TERM
      VITE 2 0.5 LECT 5 6 7 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
      FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 3 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 4 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 7 'fy_5' FLIA COMP 2 NOEU LECT 5 TERM
COUR 8 'fy_7' FLIA COMP 2 NOEU LECT 7 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 5 6 7 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
      EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
      EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
      CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
      COUR 50          REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

cqd9s3a.epx

```

CQD9S3A
ECHO
  CONV WIN
OPTI PRIN
RESU ALIC 'cqd9s3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
!      Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
      VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
      RIGH 1.00000E+00 0.00000E+00 0.00000E+00
      UP 0.00000E+00 1.00000E+00 0.00000E+00
      FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
      REFE FRAM
      INIT WIRE
      VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
      TEXT VSCA
      COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTA 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

cub802.epx

```

CUB802
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 8 CUB8 1 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 -0.5 0.5 0.5
1 2 3 4 5 6 7 8
MATE VPJC RO 7850.0

```

```

        YOUN 2.1E11
        NU   0.33
        ELAS 3.70E8
        QR1  2.364E8
        CR1  39.3
        QR2  4.081E8
        CR2  4.5
        PDOT 5.E-4
        C     0.0
        TQ    0.9      ! We assume adiabatic conditions
        CP    452.0
        TM    1800.0
        M     0.0      ! Zero M : no temperature-induced softening
        DC    1.0
        WC    15.95E8 ! Large WC : no failure (realistic value is 4.73E8)

    LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
        2.0 1.0

LINK COUP
    VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
    VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
INIT VITE 3 -0.5 LECT 1 2 3 4 TERM
    VITE 3 0.5 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
    JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER XGRD YGRD
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER XGRD YGRD
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER XGRD YGRD
TRAC 13 AXES 1.0 'STRESS [PA]' XAXE 23 1.0 'STRAIN [-]' YZER XGRD YGRD
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
    XGRD YGRD
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER XGRD YGRD
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
    EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
    EPST COMP 3 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
    CONT COMP 3 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-ZZ
    COUR 50          REFE 0.33720E+09 TOLE 5.E-3 ! FZ-SUM

FIN

```

cube02.epx

```

CUBE02
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 8 CUBE 1 TERM
-0.5 -0.5 -0.5      0.5 -0.5 -0.5      0.5 0.5 -0.5      -0.5 0.5 -0.5
-0.5 -0.5 0.5      0.5 -0.5 0.5      0.5 0.5 0.5      -0.5 0.5 0.5
1 2 3 4 5 6 7 8
MATE VPJC RO 7850.0
    YOUN 2.1E11
    NU   0.33
    ELAS 3.70E8
    QR1  2.364E8
    CR1  39.3
    QR2  4.081E8
    CR2  4.5
    PDOT 5.E-4
    C     0.0
    TQ    0.9      ! We assume adiabatic conditions
    CP    452.0
    TM    1800.0
    M     0.0      ! Zero M : no temperature-induced softening
    DC    1.0
    WC    15.95E8 ! Large WC : no failure (realistic value is 4.73E8)

    LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
        2.0 1.0

LINK COUP

```

```

    VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
    VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
INIT VITE 3 -0.5 LECT 1 2 3 4 TERM
    VITE 3 0.5 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
    JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER XGRD YGRD
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER XGRD YGRD
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER XGRD YGRD
TRAC 13 AXES 1.0 'STRESS [PA]' XAXE 23 1.0 'STRAIN [-]' YZER XGRD YGRD
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
    XGRD YGRD
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER XGRD YGRD
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
    EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
    EPST COMP 3 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
    CONT COMP 3 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-ZZ
    COUR 50          REFE 0.33720E+09 TOLE 5.E-3 ! FZ-SUM

FIN

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cube02a.epx

```

CUBE02A
ECHO
    CONV WIN
OPTI PRIN
RESU ALIC 'cube02.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 -8.29161E+00 -1.70063E-09
!      Q 7.07107E-01 7.07107E-01 0.00000E+00 0.00000E+00
    VIEW 0.00000E+00 1.00000E+00 2.05102E-10
    RIGH 1.00000E+00 0.00000E+00 0.00000E+00
    UP    0.00000E+00 -2.05102E-10 1.00000E+00
    FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.65832E+00
!RADIUS : 8.29161E+00
!ASPECT : 1.00000E+00
!NEAR : 6.46746E+00
!FAR : 1.16083E+01
SCEN GEOM NAVI FREE
    REFE FRAM
    INIT WIRE
    VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
    TEXT VSCA
    COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

cube05.epx

```

CUBE05
ECHO
!CONV WIN
LAGR TRID
DIME TTHI 50101 MNTI 701 TERM
GEOM LIBR POIN 8 CUBE 1 TERM
-0.5 -0.5 -0.5      0.5 -0.5 -0.5      0.5 0.5 -0.5      -0.5 0.5 -0.5
-0.5 -0.5 0.5      0.5 -0.5 0.5      0.5 0.5 0.5      -0.5 0.5 0.5
1 2 3 4 5 6 7 8
MATE VPJC RO 7850.0 ! Docol 600 steel parameters

```

```

YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDDT 5.E-4
C 1.E-2 ! This is 1.E-3 in Table 1 of material parameters ?
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! M = 0 : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)

LECT 1 TERM
INCLUDE 'fonc_disp.txt'
LINK COUP
DEPL 3 -0.5 FONC 1 LECT 1 2 3 4 TERM
DEPL 3 0.5 FONC 1 LECT 5 6 7 8 TERM
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO EPST
NUPA LECT 0 PAS 1 200 PAS 100 50100 TERM
FICH ALIC
NUPA LECT 0 PAS 1 200 PAS 100 50100 TERM
OPTI NOTE PAS UTIL LOG 100
JAUM
CALC TINI -3.523809523809524E-03
TEND 2.DO NMAX 50100
HIST PROG
!-3.523809523809524E-03
-3.488571428571429E-03
-3.453333333333333E-03
-3.418095238095238E-03
-3.382857142857143E-03
-3.347619047619048E-03
-3.312380952380953E-03
-3.277142857142858E-03
-3.241904761904763E-03
-3.206666666666668E-03
-3.171428571428572E-03
-3.136190476190477E-03
-3.100952380952382E-03
-3.065714285714287E-03
-3.030476190476192E-03
-2.995238095238097E-03
-2.960000000000002E-03
-2.924761904761907E-03
-2.889523809523811E-03
-2.854285714285716E-03
-2.819047619047621E-03
-2.783809523809526E-03
-2.748571428571431E-03
-2.713333333333336E-03
-2.678095238095241E-03
-2.642857142857146E-03
-2.607619047619050E-03
-2.572380952380955E-03
-2.537142857142860E-03
-2.501904761904765E-03
-2.466666666666667E-03
-2.431428571428575E-03
-2.396190476190480E-03
-2.360952380952385E-03
-2.325714285714289E-03
-2.290476190476194E-03
-2.255238095238099E-03
-2.220000000000004E-03
-2.184761904761909E-03
-2.149523809523814E-03
-2.114285714285719E-03
-2.079047619047624E-03
-2.043809523809528E-03
-2.008571428571433E-03
-1.973333333333338E-03
-1.938095238095243E-03
-1.902857142857148E-03
-1.867619047619052E-03
-1.832380952380957E-03
-1.797142857142862E-03
-1.761904761904766E-03
-1.726666666666667E-03
-1.691428571428575E-03
-1.656190476190480E-03
-1.620952380952385E-03
-1.585714285714289E-03
-1.550476190476194E-03
-1.515238095238099E-03
-1.480000000000003E-03
-1.444761904761908E-03
-1.409523809523813E-03
-1.374285714285717E-03
-1.339047619047622E-03
-1.303809523809527E-03
-1.268571428571431E-03
-1.233333333333336E-03
-1.198095238095241E-03
-1.162857142857145E-03
-1.127619047619050E-03
-1.092380952380955E-03
-1.057142857142859E-03
-1.021904761904764E-03
-9.866666666666687E-04
-9.514285714285734E-04

-9.161904761904782E-04
-8.809523809523830E-04
-8.457142857142877E-04
-8.104761904761925E-04
-7.752380952380973E-04
-7.400000000000020E-04
-7.047619047619068E-04
-6.695238095238116E-04
-6.342857142857164E-04
-5.990476190476211E-04
-5.638095238095259E-04
-5.285714285714307E-04
-4.933333333333354E-04
-4.580952380952402E-04
-4.228571428571450E-04
-3.876190476190497E-04
-3.523809523809545E-04
-3.171428571428593E-04
-2.819047619047640E-04
-2.466666666666688E-04
-2.114285714285736E-04
-1.761904761904783E-04
-1.409523809523831E-04
-1.057142857142879E-04
-7.047619047619263E-05
-3.523809523809739E-05
0.000000000000000E+00
PAS 4.D-5 2.DO TERM

SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCAR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER XGRD YGRD
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER XGRD YGRD
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER XGRD YGRD
TRAC 13 AXES 1.0 'STRESS [PA]' XAXE 23 1.0 'STRAIN [-]' YZER XGRD YGRD
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
XGRD YGRD
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER XGRD YGRD
QUAL EPST COMP 1 LECT 1 TERM REFE -0.50170E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.50170E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 3 LECT 1 TERM REFE 0.10052E+01 TOLE 1.E-3 ! EPS-ZZ
CONT COMP 3 LECT 1 TERM REFE 0.10822E+10 TOLE 5.E-3 ! SIG-ZZ
COUR 50 REFE 0.39677E+09 TOLE 5.E-3 ! FZ-SUM

FIN

cube05a.epx

CUBE05A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'cube05.ali' GARD PSCAR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 -8.29161E+00 -1.70063E-09
! Q 7.07107E-01 7.07107E-01 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 1.00000E+00 2.05102E-10
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 -2.05102E-10 1.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.65832E+00
!RADIUS : 8.29161E+00
!ASPECT : 1.00000E+00
!NEAR : 6.46746E+00
!FAR : 1.16083E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1

```

```

FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 700 FPS 25 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 698 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

cube05p.epx

```

CUBE05P
ECHO
OPTI PRIN
RESU ALIC 'cube05.ali' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR 11 'dx_1' DEPL COMP 1 NOEU LECT 1 TERM
COUR 12 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR 21 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 22 'fz_8' FLIA COMP 3 NOEU LECT 8 TERM
COUR 31 's1_gp1' CONT COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 32 's2_gp1' CONT COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 33 's3_gp1' CONT COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 34 's4_gp1' CONT COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 35 's5_gp1' CONT COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 36 's6_gp1' CONT COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 41 'SIGMAH' ECR0 COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 42 'PHI' ECR0 COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 43 'P' ECR0 COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 44 'PHITRIAL' ECR0 COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 45 'F' ECR0 COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 46 'R' ECR0 COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 47 'DDLAMBDA' ECR0 COMP 7 GAUS 1 ELEM LECT 1 TERM
COUR 48 'DLAMBDA' ECR0 COMP 8 GAUS 1 ELEM LECT 1 TERM
COUR 49 'NRITER' ECR0 COMP 9 GAUS 1 ELEM LECT 1 TERM
COUR 50 'DLAMBDA/DT' ECR0 COMP 10 GAUS 1 ELEM LECT 1 TERM
COUR 51 'D' ECR0 COMP 11 GAUS 1 ELEM LECT 1 TERM
COUR 52 'FAILURE' ECR0 COMP 12 GAUS 1 ELEM LECT 1 TERM
COUR 53 'T' ECR0 COMP 13 GAUS 1 ELEM LECT 1 TERM
COUR 54 'WE' ECR0 COMP 14 GAUS 1 ELEM LECT 1 TERM
COUR 61 'e1_gp1' EPST COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 62 'e2_gp1' EPST COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 63 'e3_gp1' EPST COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 64 'e4_gp1' EPST COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 65 'e5_gp1' EPST COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 66 'e6_gp1' EPST COMP 6 GAUS 1 ELEM LECT 1 TERM
TRAC 1 2 11 12 AXES 1.0 'DISPL. [M]' YZER XGRD YGRD
TRAC 21 22 AXES 1.0 'FZLIA [N]' YZER XGRD YGRD
TRAC 31 32 33 34 35 36 AXES 1.0 'STRESS [PA]' YZER
TRAC 61 62 63 64 65 66 AXES 1.0 'STRAIN [-]' YZER XGRD YGRD
TRAC 41 AXES 1.0 'SIGMAH' YZER
TRAC 42 AXES 1.0 'PHI' YZER
TRAC 43 AXES 1.0 'P' YZER
TRAC 44 AXES 1.0 'PHITRIAL' YZER
TRAC 45 AXES 1.0 'F' YZER
TRAC 46 AXES 1.0 'R' YZER
TRAC 47 AXES 1.0 'DDLAMBDA' YZER
TRAC 48 AXES 1.0 'DLAMBDA' YZER
TRAC 49 AXES 1.0 'NRITER' YZER
TRAC 50 AXES 1.0 'DLAMBDA/DT' YZER
TRAC 51 AXES 1.0 'D' YZER
TRAC 52 AXES 1.0 'FAILURE' YZER
TRAC 53 AXES 1.0 'T' YZER
TRAC 54 AXES 1.0 'WE' YZER
COUR 101 'x_1' COOR COMP 1 NOEU LECT 1 TERM
COUR 102 'x_2' COOR COMP 1 NOEU LECT 2 TERM
COUR 201 'y_1' COOR COMP 2 NOEU LECT 1 TERM
COUR 204 'y_4' COOR COMP 2 NOEU LECT 4 TERM
COUR 301 'z_1' COOR COMP 3 NOEU LECT 1 TERM
COUR 305 'z_5' COOR COMP 3 NOEU LECT 5 TERM
TRAC 101 102 201 204 301 305 AXES 1.0 'COOR' YZER
COUR 401 'dx' SUB 102 101
COUR 402 'dy' SUB 204 201
COUR 403 'dz' SUB 305 301
TRAC 401 402 403 AXES 1.0 'LENGTHS' YZER
COUR 404 'dxdy' MUL 401 402
TRAC 404 AXES 1.0 'AREA' YZER XGRD YGRD
COUR 405 'vol' MUL 404 403
TRAC 405 AXES 1.0 'VOLUME' YZER
TRAC 63 AXES 1.0 'STRAIN [-]' YZER
TRAC 33 AXES 1.0 'STRESS [PA]' XAXE 63 1.0 'STRAIN [-]'
XMIN 0.0 XMAX 1.1 NX 11 YMIN 0.0 YMAX 1.1E9 NY 11
YZER XGRD YGRD
COUR 505 'dt1' DT1
TRAC 505 AXES 1.0 'DT1 [s]' YZER
RCOU 601 'sz' FICH 'sigma.pun' RENA 'sz_ana'
TRAC 33 601 AXES 1.0 'STRESS [PA]' YZER XGRD YGRD
COLO NOIR ROUG
FIN

```

cube05q.epx

```

CUBE05Q
ECHO
OPTI PRIN
RESU ALIC 'cube05.ali' GARD PSCR
SORT ARRE NUPA 201 GRAP

```

```

AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR 11 'dx_1' DEPL COMP 1 NOEU LECT 1 TERM
COUR 12 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR 21 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 22 'fz_8' FLIA COMP 3 NOEU LECT 8 TERM
COUR 31 's1_gp1' CONT COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 32 's2_gp1' CONT COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 33 's3_gp1' CONT COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 34 's4_gp1' CONT COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 35 's5_gp1' CONT COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 36 's6_gp1' CONT COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 41 'SIGMAH' ECR0 COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 42 'PHI' ECR0 COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 43 'P' ECR0 COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 44 'PHITRIAL' ECR0 COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 45 'F' ECR0 COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 46 'R' ECR0 COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 47 'DDLAMBDA' ECR0 COMP 7 GAUS 1 ELEM LECT 1 TERM
COUR 48 'DLAMBDA' ECR0 COMP 8 GAUS 1 ELEM LECT 1 TERM
COUR 49 'NRITER' ECR0 COMP 9 GAUS 1 ELEM LECT 1 TERM
COUR 50 'DLAMBDA/DT' ECR0 COMP 10 GAUS 1 ELEM LECT 1 TERM
COUR 51 'D' ECR0 COMP 11 GAUS 1 ELEM LECT 1 TERM
COUR 52 'FAILURE' ECR0 COMP 12 GAUS 1 ELEM LECT 1 TERM
COUR 53 'T' ECR0 COMP 13 GAUS 1 ELEM LECT 1 TERM
COUR 54 'WE' ECR0 COMP 14 GAUS 1 ELEM LECT 1 TERM
COUR 61 'e1_gp1' EPST COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 62 'e2_gp1' EPST COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 63 'e3_gp1' EPST COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 64 'e4_gp1' EPST COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 65 'e5_gp1' EPST COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 66 'e6_gp1' EPST COMP 6 GAUS 1 ELEM LECT 1 TERM
TRAC 1 2 11 12 AXES 1.0 'DISPL. [M]' YZER
TRAC 21 22 AXES 1.0 'FZLIA [N]' YZER XGRD YGRD
TRAC 31 32 33 34 35 36 AXES 1.0 'STRESS [PA]' YZER
TRAC 61 62 63 64 65 66 AXES 1.0 'STRAIN [-]' YZER
TRAC 41 AXES 1.0 'SIGMAH' YZER
TRAC 42 AXES 1.0 'PHI' YZER
TRAC 43 AXES 1.0 'P' YZER
TRAC 44 AXES 1.0 'PHITRIAL' YZER
TRAC 45 AXES 1.0 'F' YZER
TRAC 46 AXES 1.0 'R' YZER
TRAC 47 AXES 1.0 'DDLAMBDA' YZER
TRAC 48 AXES 1.0 'DLAMBDA' YZER
TRAC 49 AXES 1.0 'NRITER' YZER
TRAC 50 AXES 1.0 'DLAMBDA/DT' YZER
TRAC 51 AXES 1.0 'D' YZER
TRAC 52 AXES 1.0 'FAILURE' YZER
TRAC 53 AXES 1.0 'T' YZER
TRAC 54 AXES 1.0 'WE' YZER
COUR 101 'x_1' COOR COMP 1 NOEU LECT 1 TERM
COUR 102 'x_2' COOR COMP 1 NOEU LECT 2 TERM
COUR 201 'y_1' COOR COMP 2 NOEU LECT 1 TERM
COUR 204 'y_4' COOR COMP 2 NOEU LECT 4 TERM
COUR 301 'z_1' COOR COMP 3 NOEU LECT 1 TERM
COUR 305 'z_5' COOR COMP 3 NOEU LECT 5 TERM
TRAC 101 102 201 204 301 305 AXES 1.0 'COOR' YZER
COUR 401 'dx' SUB 102 101
COUR 402 'dy' SUB 204 201
COUR 403 'dz' SUB 305 301
TRAC 401 402 403 AXES 1.0 'LENGTHS' YZER
COUR 404 'dxdy' MUL 401 402
TRAC 404 AXES 1.0 'AREA' YZER
COUR 405 'vol' MUL 404 403
TRAC 405 AXES 1.0 'VOLUME' YZER
TRAC 63 AXES 1.0 'STRAIN [-]' YZER
TRAC 33 AXES 1.0 'STRESS [PA]' XAXE 63 1.0 'STRAIN [-]'
XMIN 0.0 XMAX 0.01 NX 10 YMIN 0.0 YMAX 5.E8 NY 10
YZER
COUR 505 'dt1' DT1
TRAC 505 AXES 1.0 'DT1 [s]' YZER
RCOU 601 'sz' FICH 'sigma.pun' RENA 'sz_ana'
TRAC 33 601 AXES 1.0 'STRESS [PA]'
XMIN -0.005 XMAX 0.01 NX 15 YMIN 0.0 YMAX 5.E8 NY 10
YZER XGRD YGRD
COLO NOIR ROUG
TRAC 601 AXES 1.0 'STRESS [PA]'
XMIN -0.005 XMAX 0.01 NX 15 YMIN 0.0 YMAX 5.E8 NY 10
YZER
COLO ROUG
FIN

```

displ.f

```

PROGRAM displ
IMPLICIT NONE
REAL(8) :: e, a, q1, c1, q2, c2, pdot0, c, k, m
REAL(8) :: l0, dt, t2, l, t, t0, tel, dtel, d
REAL(8) :: pdotstar, b, f1, f2, sz
INTEGER :: nel, n, i

```

```

*
e      = 2.1D11
a      = 3.70D8
q1     = 2.364D8
c1     = 39.3D0
q2     = 4.081D8
c2     = 4.5D0
pdot0  = 5.D-4
c      = 1.D-2
k      = 0.5D0

```

```

m      = 0.D0
l0     = 1.D0
dt     = 4.D-5
t2     = 2.D0
nel    = 100

*
tel = 2.D0*a / e
dtel = tel / nel

*
t0 = -tel
t = t0
d = 0.D0
write (6,1) t, d
1 FORMAT (iP,2E23.15)
DO i = 1, nel
  IF (i < nel) THEN
    t = t + dtel
  ELSE
    t = 0.D0
  ENDIF
  d = 10*(exp(k*(t-t0)) - 1.D0)
  write (6,1) t, d
END DO

*
n = NINT (t2 / dt)
pdotstar = k / pdot0
b = (1.D0 + pdotstar)**c
DO i = 1, n
  t = dt*i
  f1 = q1*(1.D0 - exp(-c1*k*t))
  f2 = q2*(1.D0 - exp(-c2*k*t))
  sz = (a + f1 + f2)*b
  d = 10*(exp(sz/e + k*t) - 1.D0)
  write (6,1) t, d
END DO

*
END PROGRAM displ

```

dkT3s3.epx

```

DKT3S3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 DKT3 2 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3
3 4 1
COMP EPAI 1.0 LECT 1 2 TERM
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM

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```

COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

dkT3s3a.epx

```

DKT3S3A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'dkT3s3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 1.00000E+00 0.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

dst3s3.epx

```

DST3S3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 DST3 2 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3
3 4 1
COMP EPAI 1.0 LECT 1 2 TERM
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM

```



```

COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
      EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
      EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
      CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
      COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

dst3s3a.epx

```

DST3S3A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'dst3s3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
  RIGH 1.00000E+00 0.00000E+00 0.00000E+00
  UP 0.00000E+00 1.00000E+00 0.00000E+00
  FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
      REFE FRAM
      INIT WIRE
      VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
      TEXT VSCA
      COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTQ 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

ed0101.epx

```

ED0101
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 2 ED01 1 TERM
0 -0.5 0 0.5
1 2
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
      YOUN 2.1E11
      NU 0.33
      ELAS 3.70E8
      QR1 2.364E8
      CR1 39.3
      QR2 4.081E8
      CR2 4.5
      PDOT 5.E-4
      C 0.0
      TQ 0.9 ! We assume adiabatic conditions
      CP 452.0
      TM 1800.0
      M 0.0 ! Zero M : no temperature-induced softening
      DC 1.0
      WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)

```

```

LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
      BLOQ 13 LECT 1 2 TERM
      VITE 2 -0.5 FONC 1 LECT 1 TERM ! Relative velocity 1 m/s
      VITE 2 0.5 FONC 1 LECT 2 TERM
INIT VITE 2 -0.5 LECT 1 TERM
      VITE 2 0.5 LECT 2 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
      FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 2 TERM
TRAC 1 2 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 11 AXES 1.0 'STRESS [PA]' XAXE 21 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-XX
      EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
      EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
      CONT COMP 1 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-KX
      COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

```

fuvp01.epx

```

FUVPO1
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 2 FUN3 1 TERM
0 -0.5 0 0 0.5 0
1 2
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
      YOUN 2.1E11
      NU 0.33
      ELAS 3.70E8
      QR1 2.364E8
      CR1 39.3
      QR2 4.081E8
      CR2 4.5
      PDOT 5.E-4
      C 0.0
      TQ 0.9 ! We assume adiabatic conditions
      CP 452.0
      TM 1800.0
      M 0.0 ! Zero M : no temperature-induced softening
      DC 1.0
      WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
! BLOQ 13 LECT 1 2 TERM
      VITE 2 -0.5 FONC 1 LECT 1 TERM ! Relative velocity 1 m/s
      VITE 2 0.5 FONC 1 LECT 2 TERM
INIT VITE 2 -0.5 LECT 1 TERM
      VITE 2 0.5 LECT 2 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
      FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM

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COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 2 TERM
TRAC 1 2 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 11 AXES 1.0 'STRESS [PA]' XAXE 21 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
CONT COMP 1 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-XX
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

```

fuvp02.epx

```

FUVPO2
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 2 FUN2 1 TERM
0 -0.5 0 0.5
1 2
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 2 TERM
INIT VITE 2 -0.5 LECT 1 TERM
VITE 2 0.5 LECT 2 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 2 TERM
TRAC 1 2 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 11 AXES 1.0 'STRESS [PA]' XAXE 21 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
CONT COMP 1 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-XX
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

```

pr6002.epx

```

PR6002
ECHO
!CONV WIN

```

```

LAGR TRID
GEOM LIBR POIN 8 PR6 2 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 -0.5 0.5 0.5
1 2 3 5 6 7
3 4 1 7 8 5
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
INIT VITE 3 -0.5 LECT 1 2 3 4 TERM
VITE 3 0.5 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 13 AXES 1.0 'STRESS [PA]' XAXE 23 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 3 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
CONT COMP 3 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-ZZ
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FZ-SUM
FIN

```

pr6002a.epx

```

PR6002A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'pr6002.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 -8.29161E+00 -1.70063E-09
! Q 7.07107E-01 7.07107E-01 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 1.00000E+00 2.05102E-10
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 -2.05102E-10 1.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.65832E+00
!RADIUS : 8.29161E+00
!ASPECT : 1.00000E+00
!NEAR : 6.46746E+00
!FAR : 1.16083E+01
SCEN GEOM NAVI FREE

```

```
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTA 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN
```

pr6002p.epx

```
PR6002P
ECHO
OPTI PRIN
RESU ALIC 'pr6002.ali' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR 11 'dx_1' DEPL COMP 1 NOEU LECT 1 TERM
COUR 12 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR 21 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 22 'fz_8' FLIA COMP 3 NOEU LECT 8 TERM
COUR 31 's1_gp1' CONT COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 32 's2_gp1' CONT COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 33 's3_gp1' CONT COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 34 's4_gp1' CONT COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 35 's5_gp1' CONT COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 36 's6_gp1' CONT COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 41 'SIGMAH' ECRO COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 42 'PHI' ECRO COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 43 'P' ECRO COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 44 'PHITRIAL' ECRO COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 45 'F' ECRO COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 46 'R' ECRO COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 47 'DDLAMBDA' ECRO COMP 7 GAUS 1 ELEM LECT 1 TERM
COUR 48 'DLAMBDA' ECRO COMP 8 GAUS 1 ELEM LECT 1 TERM
COUR 49 'NRITER' ECRO COMP 9 GAUS 1 ELEM LECT 1 TERM
COUR 50 'DLAMBDA/DT' ECRO COMP 10 GAUS 1 ELEM LECT 1 TERM
COUR 51 'D' ECRO COMP 11 GAUS 1 ELEM LECT 1 TERM
COUR 52 'FAILURE' ECRO COMP 12 GAUS 1 ELEM LECT 1 TERM
COUR 53 'T' ECRO COMP 13 GAUS 1 ELEM LECT 1 TERM
COUR 54 'WE' ECRO COMP 14 GAUS 1 ELEM LECT 1 TERM
COUR 61 'e1_gp1' EPST COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 62 'e2_gp1' EPST COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 63 'e3_gp1' EPST COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 64 'e4_gp1' EPST COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 65 'e5_gp1' EPST COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 66 'e6_gp1' EPST COMP 6 GAUS 1 ELEM LECT 1 TERM
TRAC 1 2 11 12 AXES 1.0 'DISPL. [M]' YZER
TRAC 21 22 AXES 1.0 'FZLIA [N]' YZER
TRAC 31 32 33 34 35 36 AXES 1.0 'STRESS [PA]' YZER
TRAC 61 62 63 64 65 66 AXES 1.0 'STRAIN [-]' YZER
TRAC 41 AXES 1.0 'SIGMAH' YZER
TRAC 42 AXES 1.0 'PHI' YZER
TRAC 43 AXES 1.0 'P' YZER
TRAC 44 AXES 1.0 'PHITRIAL' YZER
TRAC 45 AXES 1.0 'F' YZER
TRAC 46 AXES 1.0 'R' YZER
TRAC 47 AXES 1.0 'DDLAMBDA' YZER
TRAC 48 AXES 1.0 'DLAMBDA' YZER
TRAC 49 AXES 1.0 'NRITER' YZER
TRAC 50 AXES 1.0 'DLAMBDA/DT' YZER
TRAC 51 AXES 1.0 'D' YZER
TRAC 52 AXES 1.0 'FAILURE' YZER
TRAC 53 AXES 1.0 'T' YZER
TRAC 54 AXES 1.0 'WE' YZER
COUR 101 'x_1' COOR COMP 1 NOEU LECT 1 TERM
COUR 102 'x_2' COOR COMP 1 NOEU LECT 2 TERM
COUR 201 'y_1' COOR COMP 2 NOEU LECT 1 TERM
COUR 204 'y_4' COOR COMP 2 NOEU LECT 4 TERM
COUR 301 'z_1' COOR COMP 3 NOEU LECT 1 TERM
COUR 305 'z_5' COOR COMP 3 NOEU LECT 5 TERM
TRAC 101 102 201 204 301 305 AXES 1.0 'COOR' YZER
COUR 401 'dx' SUB 102 101
COUR 402 'dy' SUB 204 201
COUR 403 'dz' SUB 305 301
TRAC 401 402 403 AXES 1.0 'LENGTHS' YZER
COUR 404 'dxdy' MUL 401 402
TRAC 404 AXES 1.0 'AREA' YZER
COUR 405 'vol' MUL 404 403
TRAC 405 AXES 1.0 'VOLUME' YZER
RCOU 501 'ez' FICH 'ez.pun' RENA 'ez_ana'
TRAC 63 501 AXES 1.0 'STRAIN [-]' YZER
COLO NOIR ROUG
TRAC 33 AXES 1.0 'STRESS [PA]' XAXE 63 1.0 'STRAIN [-]'
XMIN 0.0 XMAX 1.1 NX 11 YMIN 0.0 YMAX 1.1E9 NY 11
YZER
FIN
```

pris02.epx

```
PRIS02
ECHO
```

```
!CONV WIN
LAGR TRID
GEOM LIBR POIN 8 PRIS 2 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 -0.5 0.5 0.5
1 2 3 5 6 7
3 4 1 7 8 5
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
INIT VITE 3 -0.5 LECT 1 2 3 4 TERM
VITE 3 0.5 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 13 AXES 1.0 'STRESS [PA]' XAXE 23 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 3 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
CONT COMP 3 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-ZZ
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FZ-SUM
FIN
```

pris02a.epx

```
PRIS02A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'pris02.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 -8.29161E+00 -1.70063E-09
! Q 7.07107E-01 7.07107E-01 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 1.00000E+00 2.05102E-10
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 -2.05102E-10 1.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.65832E+00
!RADIUS : 8.29161E+00
!ASPECT : 1.00000E+00
!NEAR : 6.46746E+00
!FAR : 1.16083E+01
```

```
SCEN GEOM NAVI FREE
      REFE FRAM
      INIT WIRE
      VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
      TEXT VSCA
      COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN
```

pris02p.epx

```
PRISO2P
ECHO
OPTI PRIN
RESU ALIC 'pris02.ali' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR 11 'dx_1' DEPL COMP 1 NOEU LECT 1 TERM
COUR 12 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR 21 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 22 'fz_8' FLIA COMP 3 NOEU LECT 8 TERM
COUR 31 's1_gp1' CONT COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 32 's2_gp1' CONT COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 33 's3_gp1' CONT COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 34 's4_gp1' CONT COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 35 's5_gp1' CONT COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 36 's6_gp1' CONT COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 41 'SIGMAH' ECRO COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 42 'PHI' ECRO COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 43 'P' ECRO COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 44 'PHITRIAL' ECRO COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 45 'F' ECRO COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 46 'R' ECRO COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 47 'DDLAMBDA' ECRO COMP 7 GAUS 1 ELEM LECT 1 TERM
COUR 48 'DLAMBDA' ECRO COMP 8 GAUS 1 ELEM LECT 1 TERM
COUR 49 'NRITER' ECRO COMP 9 GAUS 1 ELEM LECT 1 TERM
COUR 50 'DLAMBDA/DT' ECRO COMP 10 GAUS 1 ELEM LECT 1 TERM
COUR 51 'D' ECRO COMP 11 GAUS 1 ELEM LECT 1 TERM
COUR 52 'FAILURE' ECRO COMP 12 GAUS 1 ELEM LECT 1 TERM
COUR 53 'T' ECRO COMP 13 GAUS 1 ELEM LECT 1 TERM
COUR 54 'WE' ECRO COMP 14 GAUS 1 ELEM LECT 1 TERM
COUR 61 'e1_gp1' EPST COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 62 'e2_gp1' EPST COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 63 'e3_gp1' EPST COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 64 'e4_gp1' EPST COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 65 'e5_gp1' EPST COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 66 'e6_gp1' EPST COMP 6 GAUS 1 ELEM LECT 1 TERM
TRAC 1 2 11 12 AXES 1.0 'DISPL. [m]' YZER
TRAC 21 22 AXES 1.0 'FZLIA [N]' YZER
TRAC 31 32 33 34 35 36 AXES 1.0 'STRESS [PA]' YZER
TRAC 61 62 63 64 65 66 AXES 1.0 'STRAIN [-]' YZER
TRAC 41 AXES 1.0 'SIGMAH' YZER
TRAC 42 AXES 1.0 'PHI' YZER
TRAC 43 AXES 1.0 'P' YZER
TRAC 44 AXES 1.0 'PHITRIAL' YZER
TRAC 45 AXES 1.0 'F' YZER
TRAC 46 AXES 1.0 'R' YZER
TRAC 47 AXES 1.0 'DDLAMBDA' YZER
TRAC 48 AXES 1.0 'DLAMBDA' YZER
TRAC 49 AXES 1.0 'NRITER' YZER
TRAC 50 AXES 1.0 'DLAMBDA/DT' YZER
TRAC 51 AXES 1.0 'D' YZER
TRAC 52 AXES 1.0 'FAILURE' YZER
TRAC 53 AXES 1.0 'T' YZER
TRAC 54 AXES 1.0 'WE' YZER
COUR 101 'x_1' COOR COMP 1 NOEU LECT 1 TERM
COUR 102 'x_2' COOR COMP 1 NOEU LECT 2 TERM
COUR 201 'y_1' COOR COMP 2 NOEU LECT 1 TERM
COUR 204 'y_4' COOR COMP 2 NOEU LECT 4 TERM
COUR 301 'z_1' COOR COMP 3 NOEU LECT 1 TERM
COUR 305 'z_5' COOR COMP 3 NOEU LECT 5 TERM
TRAC 101 102 201 204 301 305 AXES 1.0 'COOR' YZER
COUR 401 'dx' SUB 102 101
COUR 402 'dy' SUB 204 201
COUR 403 'dz' SUB 305 301
TRAC 401 402 403 AXES 1.0 'LENGTHS' YZER
COUR 404 'dxdy' MUL 401 402
TRAC 404 AXES 1.0 'AREA' YZER
COUR 405 'vol' MUL 404 403
TRAC 405 AXES 1.0 'VOLUME' YZER
RCOU 501 'ez' FICH 'ez.pun' RENA 'ez_ana'
TRAC 63 501 AXES 1.0 'STRAIN [-]' YZER
COLO NOIR ROUG
TRAC 33 AXES 1.0 'STRESS [PA]' XAXE 63 1.0 'STRAIN [-]',
      XMIN 0.0 XMAX 1.1 NX 11 YMIN 0.0 YMAX 1.1E9 NY 11
      YZER
FIN
```

q41l01.epx

Q41L01

```
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 4 Q41L 1 TERM
-0.5 -0.5 0.5 -0.5 0.5 0.5 -0.5 0.5
1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
      YOUN 2.1E11
      NU 0.33
      ELAS 3.70E8
      QR1 2.364E8
      CR1 39.3
      QR2 4.081E8
      CR2 4.5
      PDOT 5.E-4
      C 0.0
      TQ 0.9 ! We assume adiabatic conditions
      CP 452.0
      TM 1800.0
      M 0.0 ! Zero M : no temperature-induced softening
      DC 1.0
      WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
      LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
      2.0 1.0
LINK COUP
      VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
      VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
      VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINI FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
      FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [m]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 12 AXES 1.0 'STRESS [PA]' XAXE 22 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
      EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
      EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
      CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-YY
      COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN
```

q42l01.epx

```
Q42L01
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 4 Q42L 1 TERM
-0.5 -0.5 0.5 -0.5 0.5 0.5 -0.5 0.5
1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
      YOUN 2.1E11
      NU 0.33
      ELAS 3.70E8
      QR1 2.364E8
      CR1 39.3
      QR2 4.081E8
      CR2 4.5
      PDOT 5.E-4
      C 0.0
      TQ 0.9 ! We assume adiabatic conditions
      CP 452.0
      TM 1800.0
      M 0.0 ! Zero M : no temperature-induced softening
      DC 1.0
      WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
      LECT 1 TERM
```

```

FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
                2.0 1.0

LINK COUP
  VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
  VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
  VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
  FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
  JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
  EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
  EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
  CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-YY
  COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM

FIN

```

q4grs3.epx

```

Q4GRS3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 Q4GR 1 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
  YOUN 2.1E11
  NU 0.33
  ELAS 3.70E8
  QR1 2.364E8
  CR1 39.3
  QR2 4.081E8
  CR2 4.5
  PDOT 5.E-4
  C 0.0
  TQ 0.9 ! We assume adiabatic conditions
  CP 452.0
  TM 1800.0
  M 0.0 ! Zero M : no temperature-induced softening
  DC 1.0
  WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
                2.0 1.0

LINK COUP
  VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
  VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
  VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
  FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM

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COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
  EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
  EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
  CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
  COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM

FIN

```

q4grs3a.epx

```

Q4GRS3A
ECHO
  CONV WIN
OPTI PRIN
RESU ALIC 'q4grs3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
  Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
  RIGH 1.00000E+00 0.00000E+00 0.00000E+00
  UP 0.00000E+00 1.00000E+00 0.00000E+00
  FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
  REFE FRAM
  INIT WIRE
  VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
  TEXT VSCA
  COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

q4gss3.epx

```

Q4GSS3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 Q4GS 1 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
  YOUN 2.1E11
  NU 0.33
  ELAS 3.70E8
  QR1 2.364E8
  CR1 39.3
  QR2 4.081E8
  CR2 4.5
  PDOT 5.E-4
  C 0.0
  TQ 0.9 ! We assume adiabatic conditions
  CP 452.0
  TM 1800.0
  M 0.0 ! Zero M : no temperature-induced softening
  DC 1.0
  WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
                2.0 1.0

LINK COUP
  VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
  VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
  VITE 2 0.5 LECT 3 4 TERM

```

```

ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
      FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
      EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
      EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
      CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

q4gss3a.epx

```

Q4GSS3A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'q4gss3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
  RIGH 1.00000E+00 0.00000E+00 0.00000E+00
  UP 0.00000E+00 1.00000E+00 0.00000E+00
  FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
      REFE FRAM
      INIT WIRE
      VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
      TEXT VSCA
      COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

q92g01.epx

```

Q92G01
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 9 Q92 1 TERM
-0.5 -0.5
0.0 -0.5
0.5 -0.5
0.5 0.0
0.5 0.5
0.0 0.5
-0.5 0.5
-0.5 0.0

```

```

0.0 0.0
1 2 3 4 5 6 7 8 9
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
      YOUN 2.1E11
      NU 0.33
      ELAS 3.70E8
      QR1 2.364E8
      CR1 39.3
      QR2 4.081E8
      CR2 4.5
      PDOT 5.E-4
      C 0.0
      TQ 0.9 ! We assume adiabatic conditions
      CP 452.0
      TM 1800.0
      M 0.0 ! Zero M : no temperature-induced softening
      DC 1.0
      WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
      2.0 1.0
LINK COUP
      VITE 2 -0.5 FONC 1 LECT 1 2 3 TERM ! Relative velocity 1 m/s
      VITE 2 0.5 FONC 1 LECT 5 6 7 TERM
      RELA 2 EGAL 1 LECT 1 7 8 TERM
      EGAL 1 LECT 3 4 5 TERM
INIT VITE 2 -0.5 LECT 1 2 3 TERM
      VITE 2 0.5 LECT 5 6 7 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
      FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 3 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 4 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 7 'fy_5' FLIA COMP 2 NOEU LECT 5 TERM
COUR 8 'fy_7' FLIA COMP 2 NOEU LECT 7 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 5 6 7 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 12 AXES 1.0 'STRESS [PA]' XAXE 22 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
      EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
      EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
      CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

```

q92g01a.epx

```

Q92G01A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'q92g01.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
  RIGH 1.00000E+00 0.00000E+00 0.00000E+00
  UP 0.00000E+00 1.00000E+00 0.00000E+00
  FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
      REFE FRAM
      INIT WIRE
      VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
      TEXT VSCA
      COLO PAPE
SLER CAM1 1 NFRA 1

```

```

FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

q93g01.epx

Q93G01
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 9 Q93 1 TERM
-0.5 -0.5
0.0 -0.5
0.5 -0.5
0.5 0.0
0.5 0.5
0.0 0.5
-0.5 0.5
-0.5 0.0
0.0 0.0
1 2 3 4 5 6 7 8 9
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 3 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 5 6 7 TERM
RELA 2 EGAL 1 LECT 1 7 8 TERM
EGAL 1 LECT 3 4 5 TERM
INIT VITE 2 -0.5 LECT 1 2 3 TERM
VITE 2 0.5 LECT 5 6 7 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 3 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 4 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 7 'fy_5' FLIA COMP 2 NOEU LECT 5 TERM
COUR 8 'fy_7' FLIA COMP 2 NOEU LECT 7 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 5 6 7 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 12 AXES 1.0 'STRESS [PA]' XAXE 22 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

q93g01a.epx

Q93G01A
ECHO

```

```

CONV WIN
OPTI PRIN
RESU ALIC 'q93g01.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 1.00000E+00 0.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

qppss3.epx

QPPSS3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 QPPS 1 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER

```

```

TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

qppss3a.epx

```

QPPSS3A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'qppss3.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 1.00000E+00 0.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTA 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

sigma.f

```

PROGRAM sigma
IMPLICIT NONE
REAL(8) :: e, a, q1, c1, q2, c2, pdot0, c, k, m
REAL(8) :: l0, dt, t2, l, t, t0, tel, dtel, d
REAL(8) :: pdotstar, b, f1, f2, ez, sz
INTEGER :: nel, n, i, ntot

*
e = 2.1D11
a = 3.70D8
q1 = 2.364D8
c1 = 39.3D0
q2 = 4.081D8
c2 = 4.5D0
pdot0 = 5.D-4
c = 1.D-2
k = 0.5D0
m = 0.D0
l0 = 1.D0
dt = 4.D-5
t2 = 2.D0
nel = 100

*
tel = 2.D0*a / e
dtel = tel / nel

*
t0 = -tel
t = t0
sz = 0.D0
n = NINT (t2 / dt)
ntot = nel + n + 1
write (6,2) ntot
2 FORMAT ('VALUES',I6,' COMPONENTS 1',/,
> ' * Time [s] STRESS [PA]',/,
> ' * T sz')
write (6,1) t, sz
1 FORMAT (1P,2E17.6)
DO i = 1, nel
IF (i < nel) THEN
t = t + dtel
ELSE
t = 0.D0
ENDIF
d = 10*(exp(k*(t-t0)) - 1.D0)
ez = LOG ((l0+d) / l0)
sz = e*ez
write (6,1) t, sz
END DO

```

```

*
pdotstar = k / pdot0
b = (1.D0 + pdotstar)**c
DO i = 1, n
t = dt*i
f1 = q1*(1.D0 - exp(-c1*k*t))
f2 = q2*(1.D0 - exp(-c2*k*t))
sz = (a + f1 + f2)*b
d = 10*(exp(sz/e + k*t) - 1.D0)
write (6,1) t, sz
END DO

*
END PROGRAM sigma

```

t3gss3.epx

```

T3GSS3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 T3GS 2 TERM
-0.5 -0.5 0.0 0.5 -0.5 0.0 0.5 0.5 0.0 -0.5 0.5 0.0
1 2 3
3 4 1
COMP EPAI 1.0 LECT 1 2 TERM
MATE VPJC RQ 7850.0
YUUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM
COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 14 AXES 1.0 'STRESS [PA]' XAXE 24 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 1.E-2 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 1.E-2 ! FY-SUM
FIN

```

t3gss3a.epx

```

T3GSS3A
ECHO
CONV WIN
OPTI PRIN

```



```

RESU ALIC 't3gss3.ali' GARD PSCH
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 1.00000E+00 0.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTA 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

tetr02.epx

```

TETRO2
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 9 TETR 12 TERM
-0.5 -0.5 -0.5 0.5 -0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 -0.5
-0.5 -0.5 0.5 0.5 -0.5 0.5 0.5 0.5 0.5 -0.5 0.5 0.5
0 0 0
1 2 3 9
3 4 1 9
1 5 6 9
6 2 1 9
2 6 7 9
7 3 2 9
3 7 8 9
8 4 3 9
1 4 5 9
4 8 5 9
7 6 5 9
5 8 7 9
MATE VPJC RO 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 PAS 1 12 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 3 -0.5 FONC 1 LECT 1 2 3 4 TERM ! Relative velocity 1 m/s
VITE 3 0.5 FONC 1 LECT 5 6 7 8 TERM
INIT VITE 3 -0.5 LECT 1 2 3 4 TERM
VITE 3 0.5 LECT 5 6 7 8 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCH
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR 3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 4 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 5 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 6 'fz_2' FLIA COMP 3 NOEU LECT 2 TERM
COUR 7 'fz_5' FLIA COMP 3 NOEU LECT 5 TERM
COUR 8 'fz_6' FLIA COMP 3 NOEU LECT 6 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 15 's5_1' CONT COMP 5 ELEM LECT 1 TERM

```

```

COUR 16 's6_1' CONT COMP 6 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 25 'e5_1' EPST COMP 5 ELEM LECT 1 TERM
COUR 26 'e6_1' EPST COMP 6 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fz_sum' FLIA COMP 3 ZONE LECT 5 6 7 8 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'STRAIN [-]' YZER
TRAC 13 AXES 1.0 'STRESS [PA]' XAXE 23 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-YY
EPST COMP 3 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-ZZ
CONT COMP 3 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-ZZ
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FZ-SUM
FIN

```

tetr02a.epx

```

TETRO2A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'tetr02.ali' GARD PSCH
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 -8.29161E+00 -1.70063E-09
! Q 7.07107E-01 7.07107E-01 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 1.00000E+00 2.05102E-10
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 -2.05102E-10 1.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.65832E+00
!RADIUS : 8.29161E+00
!ASPECT : 1.00000E+00
!NEAR : 6.46746E+00
!FAR : 1.16083E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTA 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

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tetr02p.epx

```

TETRO2P
ECHO
OPTI PRIN
RESU ALIC 'tetr02.ali' GARD PSCH
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT 1 TERM
COUR 2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR 11 'dx_1' DEPL COMP 1 NOEU LECT 1 TERM
COUR 12 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR 21 'fz_1' FLIA COMP 3 NOEU LECT 1 TERM
COUR 22 'fz_8' FLIA COMP 3 NOEU LECT 8 TERM
COUR 31 's1_gp1' CONT COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 32 's2_gp1' CONT COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 33 's3_gp1' CONT COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 34 's4_gp1' CONT COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 35 's5_gp1' CONT COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 36 's6_gp1' CONT COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 41 'SIGMAH' ECRO COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 42 'PHI' ECRO COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 43 'P' ECRO COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 44 'PHITRIAL' ECRO COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 45 'F' ECRO COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 46 'R' ECRO COMP 6 GAUS 1 ELEM LECT 1 TERM
COUR 47 'DDLAMBDA' ECRO COMP 7 GAUS 1 ELEM LECT 1 TERM
COUR 48 'DLAMBDA' ECRO COMP 8 GAUS 1 ELEM LECT 1 TERM
COUR 49 'NRITER' ECRO COMP 9 GAUS 1 ELEM LECT 1 TERM
COUR 50 'DLAMBDA/DT' ECRO COMP 10 GAUS 1 ELEM LECT 1 TERM
COUR 51 'D' ECRO COMP 11 GAUS 1 ELEM LECT 1 TERM
COUR 52 'FAILURE' ECRO COMP 12 GAUS 1 ELEM LECT 1 TERM
COUR 53 'T' ECRO COMP 13 GAUS 1 ELEM LECT 1 TERM
COUR 54 'WE' ECRO COMP 14 GAUS 1 ELEM LECT 1 TERM
COUR 61 'e1_gp1' EPST COMP 1 GAUS 1 ELEM LECT 1 TERM
COUR 62 'e2_gp1' EPST COMP 2 GAUS 1 ELEM LECT 1 TERM
COUR 63 'e3_gp1' EPST COMP 3 GAUS 1 ELEM LECT 1 TERM
COUR 64 'e4_gp1' EPST COMP 4 GAUS 1 ELEM LECT 1 TERM
COUR 65 'e5_gp1' EPST COMP 5 GAUS 1 ELEM LECT 1 TERM
COUR 66 'e6_gp1' EPST COMP 6 GAUS 1 ELEM LECT 1 TERM
TRAC 1 2 11 12 AXES 1.0 'DISPL. [M]' YZER

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TRAC 21 22 AXES 1.0 'FZLIA [N]' YZER
TRAC 31 32 33 34 35 36 AXES 1.0 'STRESS [PA]' YZER
TRAC 61 62 63 64 65 66 AXES 1.0 'STRAIN [-]' YZER
TRAC 41 AXES 1.0 'SIGMAH' YZER
TRAC 42 AXES 1.0 'PHI' YZER
TRAC 43 AXES 1.0 'P' YZER
TRAC 44 AXES 1.0 'PHITRIAL' YZER
TRAC 45 AXES 1.0 'F' YZER
TRAC 46 AXES 1.0 'R' YZER
TRAC 47 AXES 1.0 'DDLAMBDA' YZER
TRAC 48 AXES 1.0 'DLAMBDA' YZER
TRAC 49 AXES 1.0 'NRITER' YZER
TRAC 50 AXES 1.0 'DLAMBDA/DT' YZER
TRAC 51 AXES 1.0 'D' YZER
TRAC 52 AXES 1.0 'FAILURE' YZER
TRAC 53 AXES 1.0 'T' YZER
TRAC 54 AXES 1.0 'WE' YZER
COUR 101 'x_1' COOR COMP 1 NOEU LECT 1 TERM
COUR 102 'x_2' COOR COMP 1 NOEU LECT 2 TERM
COUR 201 'y_1' COOR COMP 2 NOEU LECT 1 TERM
COUR 204 'y_4' COOR COMP 2 NOEU LECT 4 TERM
COUR 301 'z_1' COOR COMP 3 NOEU LECT 1 TERM
COUR 305 'z_5' COOR COMP 3 NOEU LECT 5 TERM
TRAC 101 102 201 204 301 305 AXES 1.0 'COOR' YZER
COUR 401 'dx' SUB 102 101
COUR 402 'dy' SUB 204 201
COUR 403 'dz' SUB 305 301
TRAC 401 402 403 AXES 1.0 'LENGTHS' YZER
COUR 404 'dxdy' MUL 401 402
TRAC 404 AXES 1.0 'AREA' YZER
COUR 405 'vol' MUL 404 403
TRAC 405 AXES 1.0 'VOLUME' YZER
RCOU 501 'ez' FICH 'ez.pun' RENA 'ez_ana'
TRAC 63 501 AXES 1.0 'STRAIN [-]' YZER
COLO NOIR ROUG
TRAC 33 AXES 1.0 'STRESS [PA]' XAXE 63 1.0 'STRAIN [-]'
XMIN 0.0 XMAX 1.1 NX 11 YMIN 0.0 YMAX 1.1E9 NY 11
YZER
FIN

```

tria01.epx

```

TRIA01
ECHO
!CONV WIN
LAGR CPLA
GEOM LIBR POIN 4 TRIA 2 TERM
-0.5 -0.5 0.5 -0.5 0.5 0.5 -0.5 0.5
1 2 3
3 4 1
MATE VPJC RD 7850.0
YOUN 2.1E11
NU 0.33
ELAS 3.70E8
QR1 2.364E8
CR1 39.3
QR2 4.081E8
CR2 4.5
PDOT 5.E-4
C 0.0
TQ 0.9 ! We assume adiabatic conditions
CP 452.0
TM 1800.0
M 0.0 ! Zero M : no temperature-induced softening
DC 1.0
WC 15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0 ! Constant function in time
2.0 1.0
LINK COUP
VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
VITE 2 0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
VITE 2 0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000

```

```

JAUM
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR 2 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR 3 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR 4 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 5 'fy_1' FLIA COMP 2 NOEU LECT 1 TERM
COUR 6 'fy_2' FLIA COMP 2 NOEU LECT 2 TERM
COUR 7 'fy_3' FLIA COMP 2 NOEU LECT 3 TERM
COUR 8 'fy_4' FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 's1_1' CONT COMP 1 ELEM LECT 1 TERM
COUR 12 's2_1' CONT COMP 2 ELEM LECT 1 TERM
COUR 13 's3_1' CONT COMP 3 ELEM LECT 1 TERM
COUR 14 's4_1' CONT COMP 4 ELEM LECT 1 TERM
COUR 21 'e1_1' EPST COMP 1 ELEM LECT 1 TERM
COUR 22 'e2_1' EPST COMP 2 ELEM LECT 1 TERM
COUR 23 'e3_1' EPST COMP 3 ELEM LECT 1 TERM
COUR 24 'e4_1' EPST COMP 4 ELEM LECT 1 TERM
COUR 32 'se_1' ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 'ep_1' ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 'fy_sum' FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 'DISPL. [M]' YZER
TRAC 5 6 7 8 AXES 1.0 'FORCE [N]' YZER
TRAC 11 12 13 14 AXES 1.0 'STRESS [PA]' YZER
TRAC 21 22 23 24 AXES 1.0 'STRAIN [-]' YZER
TRAC 12 AXES 1.0 'STRESS [PA]' XAXE 22 1.0 'STRAIN [-]' YZER
TRAC 32 AXES 1.0 'EQ. STRESS [PA]' XAXE 33 1.0 'EQ PL STRAIN [-]' YZER
TRAC 50 AXES 1.0 'TOT. FORCE [N]' YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-XX
EPST COMP 2 LECT 1 TERM REFE 0.10986E+01 TOLE 1.E-3 ! EPS-YY
EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 5.E-3 ! EPS-ZZ
CONT COMP 2 LECT 1 TERM REFE 0.10116E+10 TOLE 5.E-3 ! SIG-YY
COUR 50 REFE 0.33720E+09 TOLE 5.E-3 ! FY-SUM
FIN

```

tria01a.epx

```

TRIA01A
ECHO
CONV WIN
OPTI PRIN
RESU ALIC 'tria01.ali' GARD PSCR
SORT VISU NSTO 1
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 7.90569E+00
! Q 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
VIEW 0.00000E+00 0.00000E+00 -1.00000E+00
RIGH 1.00000E+00 0.00000E+00 0.00000E+00
UP 0.00000E+00 1.00000E+00 0.00000E+00
FOV 2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : 0.00000E+00 0.00000E+00 0.00000E+00
!RSPHERE: 1.58114E+00
!RADIUS : 7.90569E+00
!ASPECT : 1.00000E+00
!NEAR : 6.16644E+00
!FAR : 1.10680E+01
SCEN GEOM NAVI FREE
REFE FRAM
INIT WIRE
VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
TEXT VSCA
COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI NOCL NFTP 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

```

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Stimulating innovation
Supporting legislation*

